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The purpose of this report is to provide a mission and systems requirement analysis for an In-Flight Field Portable Laboratory. This system is to be an additional capability for the USAF Aeromedical Evacuation Mission specifically to evaluate the utility of an in-flight capable Aeromedical Clinical Laboratory to improve aeromedical mission effectiveness. Additional information concerning the software discussed in Appendix B is available only from Systems Research Laboratories, Incorporated.

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PREFACE

During the course of aviation history, the aeromedical evacuation of casualties resulting from battle, natural disasters, and other types of emergency and mass casualty situations has been accomplished with various levels of success. The ability to move casualties rapidly through a well-organized medical treatment and care system first by ground, and then by aircraft, to protected, centralized hospitals has increased wartime and peacetime survival rates, boosted the morale of combatants, and helped optimize the use of critical medical resources. In the Korean and Vietnam conflicts, the evacuation of casualties by helicopter, small to medium size conventional aircraft, and larger, long-range aircraft has evolved into dramatically improved survival rates. The experience of these successful aeromedical evacuation operations has evolved into the systems, subsystems, personnel, and training that make up today's United States Air Force (USAF) Aeromedical Evacuation System under the Military Airlift Command (MAC).

The Air Force Systems Command's Human Systems Division and the Armstrong Laboratory, formerly the USAF School of Aerospace Medicine (USAFSAM), are responsible for the research and development of technology, criteria, specifications, systems, and test and evaluation methodologies supporting the USAF Aeromedical Evacuation Mission. Future aeromedical operations in peacetime and wartime will transport greater numbers of medically unstable patients over longer distances. Accordingly, the mission of the USAFSAM Crew Technology Division (USAFSAM/VN)[1] is to maintain and improve the systems that enhance aeromedical evacuation mission effectiveness. One of the systems operations requiring analysis is the *In-Flight and Field Portable Clinical Laboratory* (subsequently referred to in this report as the *Aeromedical Clinical Laboratory* or *AMCL*).

Systems Research Laboratories, Inc. (SRL), a division of Arvin/Calspan, analyzed the operational and systems requirements for an in-flight and field portable laboratory/AMCL under Air Force Contract No. F33615-87-D-0652, Delivery Order 0004, for the Human Systems Division (HSD/YAC) and the USAFSAM Crew Technology Division (USAFSAM/VN), Brooks AFB, Texas. The SRL technical team, which included members from Biodynamics Research Corporation and The University of Texas at San Antonio (UTSA), are as follows:

Program Manager	Mr. Thomas L. Kingery
Mission Analysis	Mr. Robert V. Kaufman
Systems Requirements Analysis	The University of Texas at San Antonio: William A. Alter III, Ph.D. John Eftekhar, Ph.D. Philip Olivier, Ph.D.
Aeromedical Consultant	Biodynamics Research Corporation James H. Raddin, Jr., M.D.
Aeromedical Nursing Consultant	Ms. Joan Sapp

This report was prepared by Mr. Thomas L. Kingery, Mr. Robert V. Kaufman, William A. Alter III, Ph.D., John Eftekhar, Ph.D., Philip Olivier, Ph.D., and James H. Raddin, Jr., M.D.

The AMCL program enabled a close coordination of technical information and feedback by using several interactive joint contractor/USAF teams. This methodology was critical to the success of this research effort. The SRL AMCL team would like to express its appreciation and

[1] Now Armstrong Laboratory Crew Technology Division (AL/CFT)

gratitude to the following individuals for their time, patience, and professional participation in the numerous critical review and feedback sessions of the Aeromedical Clinical Laboratory Working Group (AMCLWG), and the AMCL Mission Requirements Review (MRR) meeting held at Brooks AFB, Texas, in May 1990. Without their help, this program could not have been a success.

AMCLWG

Major Garye D. Jensen, USAFSAM/VNC
Lt Col John A. Marshall, USAFSAM/VNC
Major Mark A. Cathcart, HSD/YAZ
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Col Margaret A. Seibold, Wilford Hall USAF Medical Center
Major Renee G. Sussman, 375th MAW/SGN
Plus the membership of the AMCLWG listed above.

A very special statement of appreciation goes to the professional staff at USAFSAM/VNC who tirelessly worked to ensure the success of this program: Major Garye D. Jensen, Major Regina A. Aune, and 1Lt Rebecca B. Schultz.

LIST OF ACRONYMS

AE	Aeromedical Evacuation
AFB	Air Force Base
AFSC	Air Force Systems Command
AHS	Academy of Health Sciences
AMCL	Aeromedical Clinical Laboratory
AMCLWG	Aeromedical Clinical Laboratory Working Group
ASF	Aeromedical Staging Facility
ASMRO	Armed Services Medical Regulating Office
ATC	Air Transportable Clinic
ATH	Air Transportable Hospital
Blood T&C	Blood Type and Crossmatch
BRC	Biodynamics Research Corporation
BUN	Blood Urea Nitrogen
CBC	Complete Blood Count
CBU	Cluster Bomb Units
CONUS	Continental United States
CPK	Creatine Phosphokinase
CRAF	Civil Reserve Air Fleet
CSF	Cerebrospinal Fluid
CW	Chemical Warfare
DEPMEDS	Deployable Medical Systems
DIC	Disseminating Intravascular Coagulopathy
DNBI	Disease, Nonbattle Injury
DOD	Department of Defense
DOW	Dying of Wounds
1E	First (1st) Echelon of Medical Care
2E	Second (2nd) Echelon of Medical Care
3E	Third (3rd) Echelon of Medical Care
4E	Fourth (4th) Echelon of Medical Care
ECG	Electrocardiogram
ECRI	Emergency Care Research Institute
EMI	Electromagnetic Interference
EMS	Emergency Medical System
ETE	Estimated Time Enroute
GLU	Glucose
GYN	Gynecological
HCT	Hematocrit
HGB	Hemoglobin
HSD	Human Systems Division
ISE	Ion Select Technology
JMCA	Joint Medical Control Agency

LIST OF ACRONYMS (continued)

JMRO	Joint Medical Regulatory Office
KIA	Killed in Action
KOH	Potassium Hydroxide
LED	Light Emitting Diodes
LCD	Liquid Crystal Display
MAC	Military Airlift Command
MASF	Mobile Aeromedical Staging Facility
MFW	Multiple Fragment Wound
MIA	Missing in Action
MIL-STD	Military Standards
MLA	Medical Laboratory Automation, Inc.
MRR	Mission Requirements Review
MTF	Medical Treatment Facility
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
OCC	Occult Blood
PCS	Product Comparison Systems
PT	Prothrombin Time
PTT	Partial Thromboplastin Time
RPG	Rocket Propelled Grenades
RPR	Rapid Plasma reagent
SCPS-M	Survivable Collective Protection System-Medical
SECDEF	Secretary of Defense
SGOT	Serum Glutamic Oxaloacetic Transaminases
SGPT	Serum Glutamic Pyruvic Transaminases
SRL	Systems Research Laboratories, Inc.
TAA	Total Army Analysis
TAC	Tactical Air Command
T/O	Takeoff
UPS	Uninterruptable Power Supply
USAF	United States Air Force
USAFSAM	United States Air Force School of Aerospace Medicine
UTSA	University of Texas at San Antonio
WARMED-WCD	Wartime Medical Work Center Descriptions
WBC	White Blood Count
WWII	World War II

Section 1

INTRODUCTION

This technical report includes the following:

- Analysis of the casualty data requirements in the aeromedical evacuation (AE) mission;
- Analysis and prioritization of applicable casualty diagnostic tests;
- Definition of the aeromedical mission settings in peacetime and wartime that could use an In-Flight and Field Portable Clinical Laboratory (referred to in this report as an *Aeromedical Clinical Laboratory* or *AMCL*) to enhance effectiveness;
- Results of a literature and technology survey of systems, equipment, and technologies applicable to an AMCL; and
- Determination of the initial design criteria for an AMCL.

This study and analysis was conducted by Systems Research Laboratories, Inc. (SRL), a division of Arvin/Calspan, from June 1989 through September 1990, under Contract F33615-87-D-0652, Delivery Order 0004, for the United States Air Force (USAF) School of Aerospace Medicine (USAFSAM) and Human Systems Division (HSD), Air Force Systems Command (AFSC), Brooks AFB, Texas. The completion of this report concluded the research effort.

Background

Future aeromedical operations in both peacetime and wartime will require the transport of greater numbers of medically unstable casualties over longer distances, especially for wartime operations in which injuries may be aggravated by possible contamination from chemical and biological agents as well as from fallout radiation that will further complicate the handling and care of these casualties. With limited resources, it will be essential to the mission that these resources be used effectively. Aeromedical operations in future high intensity conflicts may entail prolonged holding periods in 2nd Echelon medical facilities [Survivable Collective Protection System-Medical (SCPS-M), Air Transportable Clinic (ATC), etc.] and Mobile Aeromedical Staging Facilities (MASFs). In these settings, the capability to assess casualty clinical status will improve the use of limited resources. Casualty treatment decisions during these aeromedical operations are now based on a very limited capability to evaluate the clinical status of casualties.

Objectives

The objectives of this research effort were to assess the requirements for an AMCL (In-Flight and Field Portable Clinical Laboratory) in aeromedical operations; to determine the capability of available equipment or new technologies to satisfy these requirements; and to determine the feasibility of developing an AMCL for use in USAF aeromedical operations.

Overview

SRL was the prime contractor for the AMCL mission and systems analysis. In turn, SRL subcontracted to The University of Texas at San Antonio (UTSA) and Biodynamics Research

Corporation (BRC), and acquired expert consultant services from an experienced retired USAF flight nurse. This team possessed the expertise to perform AMCL mission and systems analysis.

UTSA is a recognized institution of university education and a diverse research and development center. The UTSA investigators listed below have experience in development of literature and technology surveys in each of three areas: biomedical, physiology, and computer database development and engineering:

- John Eftekhar, Ph.D., Mechanical Engineer, with background in bioengineering and fluid mechanics of ergogenic systems;
- Philip Olivier, Ph.D., Electrical Engineer, background in control systems design and neural networks; and
- William A. Alter III, Ph.D., Medical Sciences background in medical systems development, chemical warfare defense, and program management.

BRC is a research and consulting firm composed of physicians and engineers. Dr. James H. Raddin, Jr., board certified in aerospace medicine with extensive experience in biomedical systems development and USAF aerospace medical operations, was the key contractor team aerospace medical specialist.

Ms. Joan Sapp (USAF, retired), a private consultant, was selected to provide the contractor team aerospace flight nursing expertise. Ms. Sapp has extensive USAF flight nursing experience with over 2500 hours as an aeromedical crewmember in C-130 and C-141 AE aircraft, including many evacuation missions during the Vietnam conflict.

The general plan for this program was to analyze mission and systems requirements for an in-flight and field portable clinical laboratory to support AE missions. The requirements include independent evaluations of mission requirements and system performance criteria, assessments of the suitability of current and developmental equipment, and literature and technology surveys. There were four major elements of the technical support:

- Operations analysis of mission requirements and system performance criteria through literature searches and field trips;
- Frequent reviews with the AMCL Working Group (AMCLWG) at Brooks AFB, Texas, to assess status of analytical efforts and to provide technical guidance;
- Execute a Mission Requirements Review (MRR) involving up to 25 Department of Defense (DoD) participants to assess mission requirements, assist in a structured ordering of system performance criteria, and evaluate candidate equipment and technologies; and
- Refine the definition of operational requirements, define the AMCL preliminary design criteria, and document the total research effort in a final technical report.

SRL's technical approach involved close coordination with a selected group of DoD and civilian experts. The analysis tools and task described herein are phased similarly to the "classic" mission/systems analysis approach shown in Figure 1.

The key to the successful accomplishment of this analysis was the active involvement of DoD participants in AMCLWG meetings and of the DoD panel members in the MRR. This team approach was essential in developing relevant operational requirements and system performance criteria. The sequence of events for the AMCL study is shown in Figure 2.

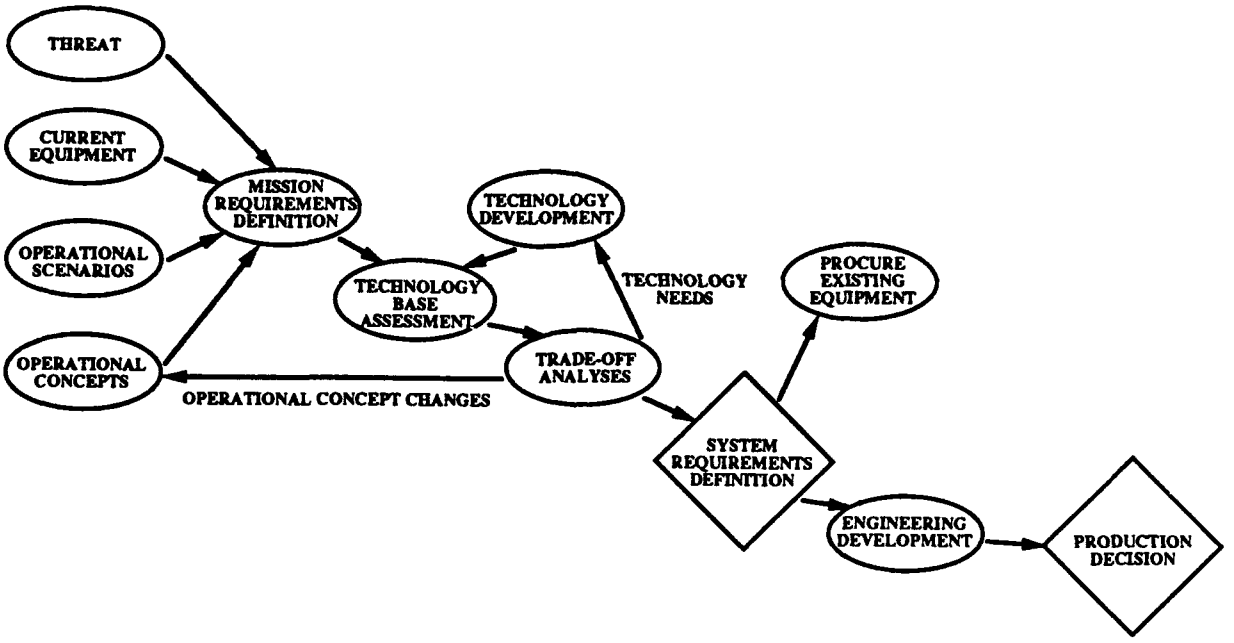

Figure 1. Systems analysis approach.

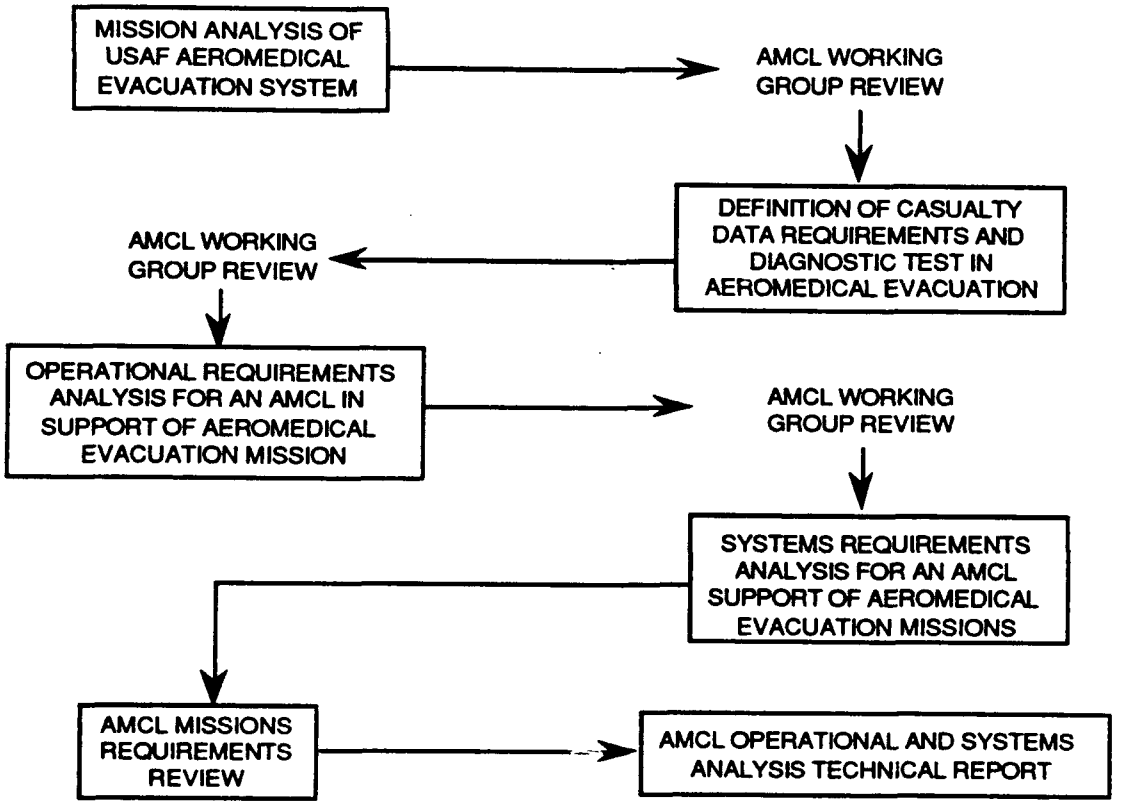

Figure 2. Sequence of events.

First, the applicable parts of the AE mission were extracted from USAF sources such as aircraft specifications and AE regulations, manuals, and teaching materials from the USAFSAM aeromedical flight nurse and technician courses. This material was presented to the AMCLWG who rated the guidance on the operational utility of the data based on actual experience. The development of aeromedical mission situations in peacetime and wartime that may require an AMCL to enhance effectiveness and development of evaluation criteria was the next step. Patient data requirements, diagnostic tests, and sampling techniques were developed and fit to the operational mission scenarios; the AMCLWG then validated the data. After SRL developed and prioritized the diagnostic tests, UTSA used this information to carry out the literature and technology survey. Site visits to USAF clinics and hospitals, including the Wilford Hall USAF Medical Center, Lackland AFB, Texas, to look at current USAF Clinical Laboratory equipment and procedures, were key events. Meetings at Fort Sam Houston, San Antonio, Texas, with the tri-service department, which develops requirements for DoD clinical laboratories, were a very informative part of the program. The status of these important program steps was reported frequently to the AMCLWG and USAFSAM/VNC. This step-by-step coupling of technical program development with the USAF research and development team on the AMCLWG was very important in the successful direction and outcome of this program.

The MRR was held in San Antonio on 30/31 May 1990 at Brooks AFB, Texas. The purpose of this review was to present a program report and to encourage interaction and guidance for needed corrections in the findings to date. The USAF MRR participants came from both the operational aeromedical evacuation and research and development communities. Participants included Military Airlift Command (MAC), Wilford Hall USAF Medical Center, USAFSAM Aeromedical Evacuation Training Program, USAF Clinical Laboratories, DoD Tri-Service Clinical Laboratory Requirements Center, and the Aeromedical Evacuation Research Development Test and Evaluation Team. This technical group of experts provided key guidance to the SRL team. With this updated information, the SRL team completed the operational and systems analysis of the AMCL and documented its findings into this technical report.

SRL designed technical risk management into this program by frequent interaction with the AMCLWG and the MRR. The area of technical risk concern was developing representative AE peacetime and wartime mission profiles, including both tactical and strategic mission settings. The methodology adopted was to use generic airbases in real USAF theaters of operation (i.e., Europe and Pacific areas) and develop representative situations. It was vitally important to balance cost-effective operational mission scenarios (i.e., a C-130 load of 70 litter casualties over a 1.5-hour duration with two full AE crews assigned) with enough realism to allow specific evaluations. This analysis technique was used to provide an audit trail of the type and number of casualties on board a particular AE mission, and the clinical/medical events that can realistically occur during the transport period with such a casualty load. This technique allows for a reasonably comprehensive and representative evaluation of the AMCL in aeromedical mission scenarios. The results of this mission scenario analysis are presented in Section 4, Operational Mission Requirements Analysis.

The UTSA literature and technology survey was bounded by the results of the operational mission analysis and the approved prioritized list of AMCL diagnostic tests. The methodology used by UTSA in the literature and technology survey was well designed and executed due to the establishment of cost-effective parameters. The results of this literature and technology survey are found in Section 6.

Section 2

CHARACTERIZATION OF THE ELEMENTS OF THE USAF AE SYSTEM

To understand the casualty data and diagnostic tests requirements, knowledge of the key elements of AE is necessary. Summarized information in this section is taken from USAF technical orders, regulations, manuals, pamphlets (i.e., AFR 164-5, Worldwide Aeromedical Evacuation) and WARMED-WCD (Wartime Medical Work Center Descriptions) Policy and Guidance.

THE MISSION

The mission of wartime casualty management is to return the maximum number of casualties to full duty within the shortest period of time. Each casualty must be assured of receiving the highest quality medical care. The DoD policy is that, both in peacetime and wartime, the movement of casualties of the Armed Forces will be accomplished by air when airlift is available and AE feasible.

AE is the movement of casualties by air transportation under medical supervision to and between medical treatment facilities. AE significantly improves recovery rates by providing rapid transport of the sick and wounded to medical facilities for treatment. The morale of combat forces is sustained by the knowledge that rapid delivery to lifesaving medical resources worldwide is readily available.

MAC is responsible for providing a worldwide AE system for the U.S. Armed Forces. As a minimum, an AE system must provide the following:

- Control of casualty movement by air transport;
- Specialized medical attendants, operational support personnel, and equipment for in-flight medical care;
- Facilities on or in the vicinity of air heads and airbases for the limited care of in-transit casualties entering, en route, or leaving the AE system; and
- Information transfers with originating, enroute, and destination medical facilities concerning casualty movement requirements.

THEATER CASUALTY MANAGEMENT

Within the theater of operations are four medical echelons or levels of care, the definition of which may vary slightly from service to service. Generally, the four echelons of care are:

- 1st Echelon (1E) or Unit Level - Provides emergency treatment only and casualties are either returned to duty or evacuated to the 2nd Echelon of care, usually by ground transportation.
- 2nd Echelon (2E) - Provides emergency care, treatment, and stabilization. Casualties not requiring admission are treated and returned to duty. Casualties who can be returned to duty within the holding period policy are admitted, treated, and returned to duty. Those requiring hospital medical or surgical attention are stabilized to permit evacuation. Rearward movement of casualties to a 3rd Echelon of care medical facility is an individual

service responsibility. Request for USAF AE from 2nd Echelon will be subject to control of the Joint Medical Control Agency (JMCA). The time between casualty entry into a 2nd Echelon facility to either return to duty or arrive at a 3rd Echelon facility (or other higher echelon of care) is 72 hours or less.

- 3rd Echelon (3E) - Usually a combat support hospital or evacuation hospital providing surgery and medical care. Subsequent movement or evacuation from 3rd Echelon facilities to the next level of care is normally by USAF aeromedical evacuation as controlled by the JMCA. The transport time of casualties between 3rd Echelon and a 4th Echelon facility normally will not exceed 6 hours.

- 4th Echelon (4E) - Treatment is provided at general hospitals whose location is determined by safety from enemy attack and accessibility to airfields capable of supporting AE aircraft. Casualties unable to be rehabilitated at 4th Echelon may be evacuated to the continental United States (CONUS) for hospital care. The transfer time of casualties between 4th Echelon and CONUS will be 24 hours bed-to-bed. A patient normally will be deemed stable enough to meet this criteria.

THEATER EVACUATION POLICY

The theater evacuation policy is established by the Secretary of Defense (SECDEF). The policy states the maximum number of days that casualties may be held within the theater for treatment. Casualties not expected to return to duty within the number of days expressed in the theater evacuation policy are evacuated as soon as their medical condition permits, and medical authorities have determined that travel will not aggravate their condition. These policies are flexible and dictated by the tactical situation. The decision to evacuate also depends on the type of evacuation and the expected level of care available in the transportation mode selected.

UNREGULATED CASUALTY MOVEMENT

Generally, the regulations do not allow for unregulated casualties to be accepted into the AE system. However, the wartime situation may require such action. In the event that the Joint Medical Regulatory Office/Armed Services Medical Regulating Office (JMRO/ASMRO) is unable to regulate casualty movement, these unregulated patients may still require AE within a theater or from the theater to the CONUS to relieve bed saturation.

AEROMEDICAL STAGING FACILITIES

Casualties entering into the AE system become a MAC responsibility until they are released to the regulated destination at Medical Treatment Facilities (MTFs). Beds and personnel are dedicated to processing these casualties. This dedicated resource is known as the Aeromedical Staging Facility (ASF). There are also mobile aeromedical staging facilities that support combat and/or disaster operations to the field.

The MASF has the following characteristics:

- Each MASF can hold and process 50 casualties at a time.

- Normally, each MASF can turn over casualty loads four times each 24 hours or 200 per 24 hours.

- In surge conditions, each MASF can turn over casualty loads six times each 24 hours for a limited time or 300 per 24 hours.

- Most casualty movement occurs in daytime--usually three casualty loads or 150 per day.
- Each MASF has supplies/equipment to sustain operations for 5 days.

AE AIRCRAFT DESCRIPTIONS

The following is a summary description of the tactical/theater and strategic aeromedical aircraft in use or in near-term planned development [i.e., Civil Reserve Air Fleet (CRAF)]. For a complete detailed description, which is beyond the scope of this report, refer to the applicable aircraft technical orders and other documents.

Tactical AE Aircraft

The following are generally considered the tactical or theater AE aircraft that would be used in peacetime or wartime operations. The primary aircraft to support tactical or theater AE is the C-130. There are plans to deploy CONUS-assigned C-9A aircraft to the combat theater in wartime conditions and function as dedicated AE assets. The C-130 will remain the prime aircraft for moving casualties from the combat zone. The C-9A primarily will move casualties from the communications zone using relatively safe airfields.

- C-9A: The basic interior configurations of the C-9A using three litter tiers are: (1) 12 litters, 28 seats for ambulatory casualties and passengers in mixed configuration, (2) 40 ambulatory casualties with three litters in a special care section, and (3) 30 litters. All C-9A litter tiers can accommodate four litters permitting a maximum of 40 casualties in full litter configurations.
- C-130: The C-130's primary mission is to support combat units, but they will be available for AE use on opportune, retrograde, or backhaul missions as the tactical situation permits. The C-130 can be configured to a maximum of 70 litters or 92 ambulatory casualties with a high density capability of 40 litters and 20 ambulatory casualties (60 total).
- CRAF MD-80: These civilian airline resources will be reconfigured to move casualties within the CONUS system. In current plans, these resources will not be deployed overseas. This aircraft can seat 155 passengers or can be configured to carry up to 45 litters in a maximum litter configuration.

Strategic AE Aircraft

Two aircraft will be used primarily in strategic AE due to their carrying capacity and long range. These aircraft are:

- C-141: The C-141 is a multipurpose aircraft that can be configured within approximately 3 hours to meet various litter and ambulatory requirements. The aircraft normally can be configured to carry 87 to 103 litters or 160 ambulatory casualties with a comfort pallet and nine crew seats.
- CRAF 767: The 767 is a wide body long-range civilian aircraft that can be activated in a national emergency and reconfigured rapidly into a dedicated AE mission. The 767 has 211 passenger seats or 99 litters and 36 seats for ambulatory casualties or 111 litters in a maximum litter configuration.

AE MISSION DURATIONS

The guidelines for mission duration between echelons of care are as follows:

- 2E to 3E: 2 hours or less using C-130 or C-9A aircraft.
- 3E to 4E: 6 hours or less for each leg flown. An aircraft mission may do several legs with patients on board. Aircraft will be C-130, C-9A, and C-141.
- 4E to CONUS: 7 to 14 hours using CRAF 767 or C-141 aircraft. Casualty criteria is 24 hours bed-to-bed.
- CONUS Movement: 2 to 5 hours is normal but several legs on one mission may be flown with patients on board. CRAF MD-80 and C-9A aircraft (in peacetime) will be used.

AE CREW DATA

The normal aeromedical crew size consists of two flight nurses and three AE technicians. Physicians can and will be used as part of the AE crews as directed. However, due to the requirement to make maximum use of these critical resources, it will not be a normal event in combat situations. For planning purposes, the ratio is one aeromedical crewmember for every ten casualties on board. Assigning two full aeromedical crews to a single AE mission with over 50 casualties on board is not unusual. Consideration is being given to increasing the size of an aeromedical crew to ten for the CRAF 767 aircraft (four flight nurses and six AE technicians).

AEROMEDICAL EQUIPMENT ON BOARD THE AIRCRAFT

The medical equipment for a particular mission varies with the mission and is carried on board by the AE crew. The variables include aircraft type, distance and flight time, type and condition of casualties, frequency of urgent patient movement requests, etc. The medical kits used normally contain respirators, suction devices, Collins traction, and various controlled substances (drugs and antidotes).

Other medical equipment may include MA-1 ventilators, baby bird ventilators, Stryker Frames, etc. The full listing of medical equipment available can be found in various USAF regulations, manuals, pamphlets, and USAF-designed handbooks (i.e., AFSC DH 2-2). Basically, there is no medical equipment available that can be used to perform what can be categorized as clinical laboratory tests for patient care and treatment decisions during AE missions.

CASUALTY TRANSFER

The medical system is designed so that casualties will receive the necessary medical care in their MTFs and return to duty as soon as possible. However, certain casualties with more serious injuries/illnesses will not be able to return to duty within the policy guidelines; these casualties will be transferred to higher echelons of care. The medical system of triage and the judgment/training of the referring physician should allow reasonably early decisions; the transfer process can begin as soon as the casualty is deemed sufficiently medically stable to endure the transportation to the next level of care. The medical decision to transfer is based on a number of factors; the most important consideration is the judgment that the casualty is sufficiently medically stabilized to endure the transfer process through an ASF/MASF (in this case, AE). The evaluation of the casualty is then dependent on the medical care available during transport. The assumption is that the more definitive the care available in the AE system, the earlier the decision can be made to transfer the unstable casualty. The need to move casualties at the earliest possible moment, once they are deemed nonduty returnable, is one of mission effectiveness for the USAF medical service.

Early movement allows the casualty to get a higher level of care sooner; expanded medical care is available at higher echelons of medical facilities. Thus, increased care in a shorter time will improve casualty survival, increase recovery level, and improve the overall quality of life factors for the casualty. The ability to move the casualty at the earliest possible time also has a significant effect on medical operational capability by freeing up beds in 2E, 3E, and 4E MTFs.

The medical decision to transfer an unstable casualty from 2E and 3E medical facilities may be significantly affected by the availability of an AMCL in the AE system.

Section 3

CASUALTY DATA REQUIREMENTS AND DIAGNOSTIC TESTS IN AE

This section establishes the factors and assumptions concerning casualty diagnostic tests and data requirements, assesses the rationale for the selection of the diagnostic tests, and prioritizes these tests and associated casualty data requirements. The analysis is based on evaluating the current aeromedical system of casualty care (see Section 2) and then using expert evaluation of a flight surgeon, aeromedical flight nurses and technicians, and clinical laboratory officers from the contractor teams and the AMCLWG. We compiled a current list of clinical diagnostic tests available at all levels of current USAF medical care facilities from battlefield aid stations to 2E medical care facilities, USAF clinics, and finally to USAF medical centers of which Wilford Hall USAF Medical Center is the largest. Once this list was established, the data were evaluated against a set of casualty care assumptions in aeromedical operations and known operational conditions. This analysis produced a set of preliminary casualty data requirements and diagnostic tests. This preliminary set was repeatedly evaluated against: (1) the current state of technology of that particular test; (2) the biological sampling techniques, sizes, and methods required for that test; (3) the skill levels and training requirements of the medical personnel who would be taking the samples; and (4) the additional workload impact on these critical resources.

Once the prioritized set of diagnostic tests and casualty data requirements was established, the value of each test in terms of casualty care in peacetime and wartime aeromedical mission setting was evaluated. That information is presented in Section 4.

THE CASUALTY TRANSFER DECISION

The medical and/or operational decision to transfer casualties who cannot be returned to duty within the policy guidelines requires a considerable amount of coordination and probably differs at each echelon of care. One can imagine the demanding situation at a battlefield aid station or USAF 2E medical facility just after a major attack or mass influx of casualties which taxes medical personnel and facilities. Under these conditions, it may be difficult to evaluate and stabilize a casualty to allow AE to a 3E MTF. Basic respiratory and circulatory stabilization with fluid administration may be the only medical care given, especially true when one must free up triage, treatment/stabilization, and holding beds for a large number of incoming battle-injured casualties. This situation, coupled with a fully loaded C-130 AE mission, can tax the medical care of casualties to the maximum. The level and quality of medical records or casualty data will depend on the time available to prepare the documents. A 2E medical facility will not have a full-service clinical laboratory; consequently, detailed laboratory test results on a casualty will not usually be available. This tactical/theater aeromedical situation is very different from transferring casualties from a 3E MTF to a 4E MTF or CONUS hospital.

Transferring casualties from a 3E to a 4E MTF or 4E to CONUS MTF will be more regulated and controlled than from a 2E to 3E MTF under combat or disaster/mass casualty situations. First of all, the casualties will have received better medical/surgical care and, thus, be more stable; medical records will be detailed. They probably will have had blood type and crossmatch (blood T&C), and respiratory, circulatory, and fluid administration care, as well as needed surgery. This is not to say that some operational pressure will not be present in moving casualties from 3E and 4E MTFs or beyond to free up critical bed and treatment space. But the best expert opinion of medical specialists is that the decision to transfer casualties from 3E MTFs will be significantly more controlled than from 2E. Again, the medical stability of the casualty in relation to the stress of AE will be the deciding factor. The more care available during the AE mission, the earlier the

transfer can occur and the less stable the casualty needs to be. The 3E MTF will have a very capable clinical laboratory; therefore, most, if not all, required laboratory tests and results will be available in the casualty records. The currency of the laboratory results, which will impact treatment/care decisions during AE transfer, is another issue of concern (i.e., blood gases, hematocrit, electrolytes, glucose, etc.).

The transfer decision from a 4E MTF to CONUS via Strategic AE is a medically controlled situation dependent on the location, capability, and mission of such MTFs. These casualties will be carefully evaluated for stability prior to entering the AE system. We emphasize that all medical contingencies cannot be evaluated; casualties can and do have medical emergencies in the transfer system requiring expert medical evaluation for treatment/care decisions. Medical decisions to transfer are again based on the level of care available in the AE system, as well as the stability of the casualty prior to the transfer decision. The 4E MTFs will have capable clinical laboratories and reasonably complete casualty data based on these laboratory tests, treatment to date, etc. Physicians can direct medical orders in these records for treatment, fluid administration, blood transfer, medications, and observation requirements during the AE mission. Due to the mission length or the time casualties are in this transfer process, the level of observation and care under AE medical crewmember's supervision is the longest of all missions. The casualty can be in transfer up to 24 hours bed to bed.

CLINICAL LABORATORY DIAGNOSTIC TESTS AND RESULTING CASUALTY DATA

The level of clinical laboratory testing capability is very different at each echelon of care. Fundamentally, 1E has no facilities or very limited mobile testing capabilities at Battlefield Aid Stations. In the USAF, the 2E facility has limited clinical laboratory capability such as complete blood count (CBC), urinalysis, gram stain, etc. These 2E facilities only have clinical laboratory capabilities necessary to return the casualty to duty or evacuate them to 3E MTFs as soon as possible.

The 3E MTFs have more clinical laboratory equipment and, although not standardized across all 3E MTFs, will have test capabilities in the following categories:

- Chemistry Procedures,
- Hematology/Urinalysis Procedures,
- Microbiology/Serology Procedures, and
- Blood Bank Procedures.

As a basis for a transfer decision for unstable casualties, the 3E MTFs can perform the following tests: electrocardiograms (ECG), blood gases, electrolyte, hematocrit, blood glucose, blood T&C, occult blood, cerebrospinal fluid (CSF), complete blood count, urinalysis, gram stain, cholinesterase, and others.

The 4E MTFs will have complete clinical laboratory capabilities and will be able to do the following categories of tests:

- Chemistry Procedures,
- Hematology/Urinalysis Procedures,
- Microbiology/Serology Procedures,
- Blood Bank Procedures, and
- Anatomic Pathology/Cytology Procedures.

The 4E clinical laboratory will have more capability than a 3E MTF in most of the above categories, especially in Microbiology/Serology and Anatomic Pathology/Cytology Procedures. All necessary clinical laboratory tests can be performed to enable a controlled medical transfer decision. However, since the transfer time for a casualty from 4E MTFs to CONUS via AE is up to

24 hours bed to bed, the currency of a particular test is important. Blood gases, electrolytes, hematocrit, blood glucose, etc., require near term frequency to enable immediate medical treatment/ care decisions.

CASUALTY DATA REQUIREMENTS

The USAF medical system requires that medical records and data on casualties be prepared in a fairly standard format. These medical records usually include identification information and medical histories (records of past visits, diagnosis, treatments, physicals, etc.). During wartime or peacetime mass casualty situations, transferring a casualty's complete medical historical record beginning at 1E and 2E may not be possible. However, as a casualty is triaged, stabilized, and transferred to higher levels or echelons of medical care, a medical record is accumulated. To make transfer decisions, an unstable patient's medical records are critical information, especially laboratory test results and medications/fluids administered. The information in these medical records or casualty data sets may not be properly formatted for a preflight assessment by medical crewmembers. Voluminous records do not guarantee a clear and accurate preflight assessment. The USAF AE crews normally use a preflight assessment form such as MAC Form 458, "Patient Transfer Record." The basic medical condition prompting the casualty's transfer will guide the assessors to the extent of information necessary for a safe medical transfer. Usually, a mission report is needed detailing the significant medical events during transfer such as fluids and medications/drugs given, and medical details of the casualties in-flight care and the casualty's condition upon transfer to an MTF's control. This recordkeeping, of course, depends on factors such as mission type, aircraft, flight time, workload of the medical crew, events in flight, etc. Transfer by aircraft requires special considerations unique to that environment. Some injuries and medical conditions are more susceptible to the rigors and environmental conditions experienced in flight.

Medical records are collected by physicians, nurses, medical technicians, clinical laboratory technicians, and administrators since a detailed medical history contributes to the immediate and long-term care of a casualty. These records may provide research data to reveal trends and may be used to compile summaries for planning purposes or overall research investigations. Certainly, the potential of modern day data processing methods can be made exceptionally useful to this patient information gathering process in terms of accuracy, standardization, format, transferability, and quick reviews of medical trend information. Routine medical data and records have critical importance to the immediate care of a casualty, to the medical state determination or stability assessment for a transfer decision, to the recording of medical events during the transfer process, and to the overall long-term recovery and quality of life of the casualty.

ASSUMPTIONS FOR CASUALTY DATA REQUIREMENTS AND DIAGNOSTIC TESTS

The ability to generate useful casualty data is based on three sources of integrated information:

- Expert Personal Observation (by physicians, nurses, medical technicians, etc.)
- Physiological/Medical Monitoring (blood pressure, temperature, respiration, pulse, etc.)
- Clinical Laboratory (blood count, urinalysis, chemistry, etc.)

The integration of this system of generating relevant casualty data is shown in Figure 3.

Based on this simplified concept of sources of casualty data, the medical consultants, in agreement with the AMCLWG, derived the following assumptions for casualty data requirements in the AE system. The categories are arranged in priority for casualty care decisions.

- Category I: Data needed to make an immediate treatment decision.
- Category II: Data needed that may influence later treatment decisions.
- Category III: Data needed for long-term care and administration of casualties.

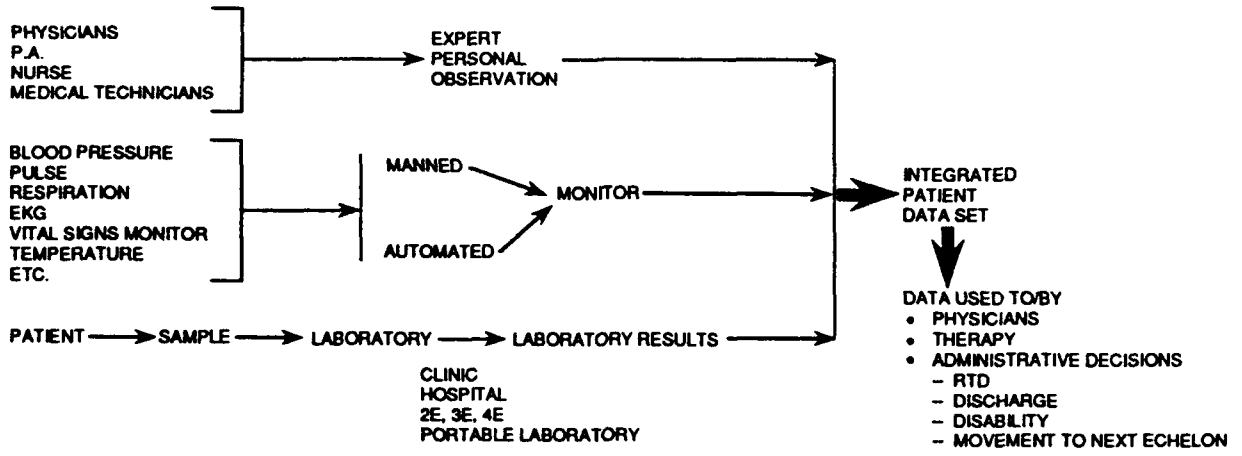

Figure 3. Casualty data sources.

Category I: Data Needed to Make an Immediate Treatment Decision

In the AE aircraft environment, the most important set of data on a casualty is that which affects immediate treatment decisions, especially if the casualty is in medical distress or in a medical crisis situation. Basic treatment methods in this situation include the status of respiration and circulation. For example, for respiratory distress, the expert decision may be to put the casualty on a respirator. Knowing the blood gases as soon as possible is useful to determine appropriate respirator settings. If a casualty has had significant levels of fluids administered and/or a blood transfusion, then knowledge of electrolytes and hematocrit is useful for medical treatment decisions. A casualty requiring insulin or who suddenly becomes unstable may require a blood glucose test to make informed treatment decisions immediately.

Category II: Data Needed that May Influence Later Treatment Decisions

During AE missions, it will be necessary to accumulate casualty data that may influence later treatment decisions at the next MTF or in long-term recovery. Certainly records on significant medical events such as loss of consciousness, convulsions, or other medical distress events are important. The ability to monitor and record the patient's physiological status (respiration, heart rate, blood pressure, etc.) may be very important. Test results for occult blood in vomit or CSF will provide significant information for the attending physician at the next MTF. A record of blood gases in terms of trends, hematocrit, and electrolytes may also influence later treatment decisions. Although not absolutely essential to survival of the casualty during the AE mission, these data will assist in later treatment decisions.

Category III: Data Needed for Long-Term Care and Administration of Casualties

All medical data related to the diagnosis, treatment, care, and medical events can potentially affect long-term care, quality of life, and administration of a casualty. The record of significant events during transfer is also relevant, especially if those data reveal trends or other significant medical information. Therefore, data on medical issues that affect long-term casualty functions are significant, as well as data on applicable clinical laboratory tests.

PRELIMINARY CASUALTY DATA REQUIREMENTS AND DIAGNOSTIC TESTS

Based on the preliminary assessment of casualty data requirements and categories/priorities of those requirements as outlined previously in this section, the following list of preliminary diagnostic tests for an AMCL was established for evaluation by the contractor expert medical team and the AMCLWG:

- Blood Gases (arterial blood O_2 and CO_2 and/or pH)
- Electrolyte (Na, K, Cl)
- Hematocrit
- Blood Glucose
- Test for Occult Blood
- CSF
- Blood T&C
- Complete Blood Count (WBC, HGB, HCT)
- Urinalysis
- Gram Stain
- Platelet Estimate/Count
- White Cell Count
- Cholinesterase
- PTT
- BUN

Discussion Summary of Preliminary Casualty Data Requirements and Diagnostic Tests

- Blood Gases: This test is considered a Category I Casualty Data Requirement. Data from this test are needed to make critical immediate treatment decisions. The area of medical concern is that of respiratory assistance for those casualties who board an AE aircraft on respirators, or for casualties who go into respiratory distress during the mission. Certainly, chemical warfare agent casualties will be prime candidates for respiratory assistance. If time permits, it is considered good medical practice to do limited blood gas tests to determine efficient respirator settings. The key blood gas tests determine arterial blood O_2 by either partial pressure of oxygen (PaO_2) or O_2 saturation levels and/or arterial blood CO_2 by either partial pressure of carbon dioxide ($PaCO_2$) or pH (if CO_2 levels are elevated, the pH is down). The data from the blood gas tests provide important information for decisions about respiratory options in terms of settings for O_2 fraction, tidal volume, and/or respiratory rate. As blood gas concentrations can change quickly, tests performed at MTF clinical labs will have little or no bearing later during an AE in-flight situation with reduced barometric pressures. The AMCLWG discussed the need for arterial blood for this test and the problem of a difficult arterial stick to gain the necessary sample in the AE aircraft environment. The difficulty of obtaining the arterial sample in the vibrating airframe of a C-130 versus the much smoother flight in a CRAF 767 differs somewhat. The training factor to do the sampling via an arterial stick for AE crews is another issue of concern. Noninvasive technologies to get relevant blood/gas status are obvious options for evaluation.

- Electrolytes: With an unstable casualty under intensive blood and fluid administration, electrolyte problems may arise based on the amount of blood/fluid administration over time. If the sodium (Na) and potassium (K) count can be determined in a limited electrolyte test, the medical practitioners on board an AE mission can fairly accurately determine what kind and amounts of fluids to administer, which may be a critical treatment (Category I) casualty data input. This decision will be based on observation and monitors (pulse/blood pressure) and test results over a few hours. These test results will also impact Category II data requirements (later treatment decision) at the next MTF. The attending physician can evaluate the

test results and fluid administration to determine the next treatment and diagnosis. The initial evaluation of samples required appears feasible in the AE environment.

- Hematocrit: The same rationale as for electrolytes applies to hematocrits for fluid and blood administration, and as an indication of possible internal bleeding. This test is considered a Category I and II casualty data requirement (immediate and later treatment decisions). During the AMCLWG discussion, the electrolyte and hematocrit tests seemed to have more application in the longer AE missions (more than 2 to 3 hours) than in the shorter tactical missions. The initial evaluation of test sampling required appears feasible in the AE environment.

- Blood Glucose: A casualty who may require insulin and/or who is in post-surgical condition requiring frequent blood glucose evaluation and, thus, is deemed unstable may be transported earlier if blood glucose tests are available. This test is fairly simple to perform and allows direct therapy decisions. There is probably more application to the longer duration AE missions, but scenarios can be generated in which casualties in the tactical AE mission would be tested. This is considered both a Category I, II, and possibly III casualty data requirement (immediate, later, and long-term treatment decisions).

- Blood T&C: After discussion, blood T&C was not considered a variable casualty data requirement. As blood T&C does not change, it was not a viable candidate for the AMCL.

- Test for Occult Blood: This is a simple test to perform, usually involving a color sensitive stick for body fluids. Vomitus is a useful test to judge for internal bleeding. As this test is a current event, it is considered useful in all AE mission scenarios (Tactical/Theater, and Strategic). It was considered a Category I and II casualty data requirement (immediate and later treatment decision) as it can influence in-flight fluid administration decisions and be very useful information for the next MTF attending physician.

- CSF Test: This is a simple stick color matching test to see if clear fluids are positive. If so, no immediate treatment decision will be affected, but certainly this information will be important to the next attending physician. It was agreed this test has application for all AE mission scenarios (Tactical/Theater, and Strategic). It is considered a Category II and III casualty data requirement (later and long-term treatment decisions).

- Complete Blood Count [White Blood Count (WBC), Hemoglobin (HGB), HCT]: This test was not considered appropriate or necessary in an AE mission. The CBC test should be performed as needed in ground-based clinical laboratories prior to or just after the AE mission to satisfy casualty data requirements.

- Urinalysis, Gram Stain, White Cell Count, and BUN: After discussion, these tests were not considered appropriate for the AE mission as they can be done just prior to and/or just after the AE mission to satisfy casualty data requirements.

- Cholinesterase: This test is usually given to chemical warfare agent casualties as a diagnostic and treatment effectiveness casualty data requirement. However, this test was not considered vital for in-flight testing as other means of treatment decisions are available; this test should be performed in the MTF ground based clinical laboratory. If the casualty requires treatment based on a cholinesterase test/data result, that treatment can be prescribed before the AE mission. Determination of cholinesterase in flight would not change the treatment decision.

CASUALTY DATA REQUIREMENTS AND DIAGNOSTIC TESTS

Based on the results of establishing the casualty data requirements, prioritized categories, and the preliminary diagnostic tests, and having the contractor aeromedical team and the AMCLWG evaluations, the list of casualty data requirements and diagnostic tests applicable to an AMCL during aeromedical operations is shown in Table 1. This list formed the basis for evaluation of an AMCL in the operational requirements analysis in Section 4.

TABLE 1. CASUALTY DATA REQUIREMENTS AND DIAGNOSTIC TESTS

	MASF	Tactical/Theater	ASF	Strategic AE Mission
Blood Gases	I, II	I, II	I, II	I, II
Electrolyte	I, II	I, II	I, II	I, II
Hematocrit	I, II	I, II	I, II	I, II
Blood Glucose	I, II, III	I, II, III	I, II, III	I, II, III
Occult Blood	I, II	I, II	I, II	I, II
CSF	II, III	II, III	II, III	II, III

I - Immediate treatment decisions.
II - Later treatment decisions.
III - Long-term care treatment decisions.

Section 4

OPERATIONAL REQUIREMENTS ANALYSIS FOR IN-FLIGHT AND FIELD PORTABLE CLINICAL LABORATORY SUPPORT OF AE MISSIONS

This section addresses an operational requirements analysis for AMCL support of aeromedical operations. The summary characterization of the AE system was presented in Section 2 with a review and analysis of the casualty data requirements and diagnostic test presented in Section 3. The operational mission analysis in this section shall briefly cover some applicable casualty generation data based on historical information, WARMED-WCD policy, and data from the U.S. Army Academy of Health Sciences (AHS). As this is an unclassified effort, no classified sources were used. The methodology is: (1) understand the rationale behind the casualty generation figures, (2) use generic airbases or operational situations that resemble actual USAF operational missions, (3) create attack scenarios based on unclassified sources, (4) generate casualties that flow through USAF medical facilities into the aeromedical evacuation system, and (5) present a medically relevant operational mission where an AMCL can be evaluated. The goal is to create scenarios in which the casualty loads on the presented individual aeromedical mission will be as realistic as can be forecast with some defensible basis. The operational scenario was prepared, presented to the AMCL MRR in May 1990, and found to be acceptable in terms of realistic situations in which the AMCL could be properly evaluated. The key questions to be answered by this section were the same as presented in the AMCL MRR:

- Does an AMCL help in casualty survival?
- Does an AMCL help improve casualty care?
- Is an AMCL useable in the operational environment of aeromedical evacuation?
- Can the medical staff, skills, and time be made available to use an AMCL during aeromedical evacuation missions?

CASUALTY GENERATION

Under conventional wartime situations, casualties can be expected to have similar treatment needs to those of past military conflicts. Based on historical data, injury, wounds, and nonbattle related disease can be characterized with various degrees of confidence. Application of new conventional weapons and levels of expected conflict can be somewhat factored into the equation. The DoD and USAF have spent considerable effort developing casualty generation models and methods that are very expensive and usually classified. That methodology was not planned in this effort due to cost and need. The relevant operational evaluation was to combine a particular AE mission with a casualty load to produce a series of medically relevant events in flight in which an AMCL can be evaluated for effectiveness (i.e., a C-130 with 70 litter patients on board, 2-hour mission duration, two full AE crews). To have some relevance, the contractor team used historical casualty data from World War II (WWII), Korea, and Vietnam, and unclassified data from the U.S. Army Academy of Health Sciences Total Army Analysis 90 (TAA90), which describes a conventional conflict with air parity in 1990, as well as, Deployable Medical Systems (DEPMEDS) and WARMED-WCD sources. Table 2 shows percent of distribution for anatomical location of wounds for those killed, dying of wounds, and the living wounded for the U.S. Army in WWII, Korea, and Vietnam. Table 3 presents DEPMEDS breakout of patients into major categories covering a 30-day period for a 19-division NATO force. Table 4 lists the most critical life threatening wartime injuries (TAA90). None of these tables of data include injury or trauma from chemical warfare and/or nuclear radiation exposure. These threats are mentioned in the contract background information; therefore, the chemical warfare casualties are included in the following operational mission analysis.

TABLE 2. PERCENT DISTRIBUTION FOR ANATOMICAL LOCATION OF WOUNDS

	Head	Neck	Thorax	Abdomen	Extremities
WWII					
Killed	40	9	23	17	12
DOW*	20	6	19	31	23
Wounded**	8	9	7	7	69
Korea					
Killed	38	10	23	14	11
DOW*	25	7	20	30	15
Wounded**	7	11	8	7	66
Vietnam					
Killed***	34	8	41	10	7
Killed***	46	8	34	7	5
DOW*	46	8	34	7	5
Wounded***	17	17	9	6	69

* Dying of wounds.
** Wounded who lived.
*** Data from two different sources.

©Source: Carey, Michael E., Learning from traditional combat mortality and morbidity data used in the evaluation of combat medical care. Military Medicine, Jan: 6-13, 1987. DEPMEDS Policies/Guidelines Treatment Briefs, July 1987.

TABLE 3. PREDICTED NATO BREAKOUT OF CASUALTIES INTO MAJOR INJURY CATEGORIES

Major Categories	Percent of Admissions
Head	10.2
Maxillo-Facial	3.4
Eye/Ear Injuries	2.1
Spine	0.8
Upper Limbs	22.8
Thorax	15.7
Abdomen and Pelvis	17.7
Lower Limbs	31.2
Burns	3.7
Misc NBI	0.0
MFW (Multiple Fragment Wound)	21.8
Head/Cold	0.9
Surgical Diseases	4.6
Dermatological	2.1
Eye/Ear Diseases	1.1
Respiratory	2.5
Gastrointestinal	4.1
Cardiovascular	0.7
Sexually Transmitted Diseases	0.4

TABLE 3. PREDICTED NATO BREAKOUT OF CASUALTIES INTO MAJOR INJURY CATEGORIES (continued)

Major Categories	Percent of Admissions
Genito-Urinary	1.0
Diseases-General	1.6
Neoplasms	0.0
Psychiatric	4.5
Combat Stress	3.3
Female Specific	1.3
Colostomy	8.5
Liver	2.0
Amputation (upper limbs)	1.0
Amputation (lower limbs)	5.6
Vascular Repairs	6.9
Class I Hemorrhage	3.9
Class II Hemorrhage	13.0
Class III Hemorrhage	22.8
Class IV Hemorrhage	15.6

Source: DEPMEDS Policies/Guidelines Treatment Brief (unclassified), July 1987.

TABLE 4. MOST CRITICAL (LIFE THREATENING) WARTIME INJURIES IN PRIORITY ORDER

1. MFW chest with pneumohemothorax, soft tissue injury to upper limbs, and penetrating wound of brain.
2. MFW brain and lower limbs requiring bilateral above knee amputations.
3. MFW chest with pneumohemothorax and limbs with fracture and vascular injury.
4. MFW abdomen and limbs with penetrating, perforating, perforating wound of colon and open fracture, and neurovascular wound of salvageable lower limb.
5. MFW chest with pneumohemothorax, soft tissue injury to upper limbs, with abdomen, with wound of colon.
6. Wound, face, jaws, and neck, open, lacerated with associated fractures, excluding spinal fractures, severe--with airway obstruction.
7. MFW brain and chest with sucking chest wound and pneumohemothorax.
8. MFW abdomen and chest with multiple organ damage.
9. MFW abdomen, pelvis, limbs, with fracture and neurovascular injury, limb salvageable, and penetrating wound, kidney.
10. MFW brain and abdomen with penetrating, perforating wound, colon.
11. Wound, lower leg, open, lacerated penetrating, perforating, with fracture and nerve/vascular damage, limb salvageable.
12. Wound, face, jaws, and neck, open lacerated with associated fractures, excluding spinal fractures, moderate--without airway obstruction.
13. Wound, thigh, open, lacerated, penetrating, perforating with fracture and nerve/vascular injury, limb salvageable.
14. MFW, abdomen and limbs, without fracture or nerve injury, with penetrating wound of liver.
15. Wound, thorax (anterior or posterior), open, penetrating, with associated rib fractures and pneumohemothorax, acute, severe respiratory distress.

TABLE 4. MOST CRITICAL (LIFE THREATENING) WARTIME INJURIES IN PRIORITY ORDER (continued)

16. Wound, upper arm, open with fractures and nerve injury, no vascular injury, arm salvageable.
17. MFW brain and abdomen with penetrating, perforating wound, kidney.
18. Intracranial hemorrhage, spontaneous, nontraumatic, severe--comatose or semicomatose, with possible respiratory distress without associated hematoma.
19. MFW brain and abdomen with shock and penetrating, perforating wound, liver.
20. Burn, thermal, full thickness, lower extremities, and genitalia, greater than 30 percent but less than 40 percent of total body area involved.
21. Burn, thermal, full thickness, lower extremities, and genitalia, greater than 15 percent but less than 30 percent of total body area.
22. Wound, shoulder girdle, open, with bone injury, severe--joint involvement.
23. Cerebral contusion with open skull fracture, severe--with intracranial fragments and/or depressed skull fracture.
24. MFW brain and abdomen with shock and penetrating, perforating wound, spleen.
25. Wound, fingers, open, lacerated, contused, crushed, with fracture(s) of phalangeals, requiring rehabilitation.
26. MFW abdomen, pelvis, limbs, without fracture or neurovascular injury, and penetrating, perforating wound, bladder.
27. MFW abdomen and lower limbs, with fracture and nerve injury, with penetrating wound of spleen.
28. MFW brain and abdomen with penetrating, perforating wound, bladder.
29. Wound, lower leg, open, lacerated, penetrating, perforating, with fracture and nerve/vascular injury, limb not salvageable.
30. Cerebral contusion, closed with depressed skull fracture, severe--with associated intracerebral hematoma and/or massive depression.
31. Wound, ankle/foot, toes, open, penetrating, perforating, with fractures and nerve/vascular injury, limb salvageable.
32. Eye wound, lacerated, moderate--without retinal detachment or retinal injury, no foreign body retained, without loss of vitreous fluid, patient has hyphema, eye salvageable.
33. MFW chest with pneumohemothorax and abdomen with penetrating wound, colon.
34. MFW with pneumohemothorax and abdomen with penetrating wound, spleen.
35. Cerebral contusion, closed, with intracranial hematoma, with or without nondepressed linear skull fracture, severe--large hematoma (including epidural hematoma) with rapidly deteriorating comatose patient.
36. Wound, thigh, open, lacerated, penetrating, perforating with fracture and nerve/vascular injury, limb not salvageable.
37. Cerebral contusion, closed, with/without nondepressed linear skull fracture, severe--loss of consciousness greater than 24 hours.
38. MFW chest with pneumohemothorax and abdomen with penetrating, perforating wound, liver.
39. Burn, thermal, full thickness, trunk, greater than 10 percent but less than 20 percent of total body area involved.
40. MFW chest with pneumohemothorax, pelvis and abdomen, with wound of colon and bladder.
41. Eye wound, severe--loss of intraocular fluid, with/without retinal detachment, eye not salvageable.
42. MFW chest (with pneumohemothorax) and abdomen with penetrating perforating wound, kidney.
43. Burn, thermal, full thickness, trunk, greater than 20 percent but less than 30 percent of total body area involved.

TABLE 4. MOST CRITICAL (LIFE THREATENING) WARTIME INJURIES IN PRIORITY ORDER (continued)

44. Wound, hand, open, lacerated, contused, crushed, with fracture(s), all cases--involving fractures of carpals and/or metacarpals.
45. Wound, thorax (anterior or posterior), open penetrating, with associated rib fractures and pneumohemothorax, moderate respiratory distress.
46. MFW chest with pneumohemothorax and abdomen with perforating wound, bladder.
47. Wound, shoulder girdle, open, with bone injury, moderate--no joint involvement.
48. Burn, thermal, partial thickness, lower extremities and genitalia, greater than 30 percent but less than 40 percent of total body area.
49. Wound, upper arm, open with fractures and nerve and vascular injury, arm nonsalvageable.
50. Burn, thermal, full thickness, upper extremities, greater than 10 percent but less than 20 percent of total body area.

ANALYSIS OF AE MISSION SETTINGS IN PEACETIME AND WARTIME

The analysis process used includes the following:

- Define a generic USAF airbase/installation.
- Define an attack/operational scenario.
- Establish a list of casualties.
- Define the casualty loads for aeromedical evacuation.
- Define and analyze the AE mission scenario with emphasis on medical utility of an AMCL in terms of mission effectiveness.

The level of analysis performed and presented to the AMCL MRR included the operational scenarios presented below. The range of the resultant AE mission was designed to be comprehensive in terms of workload and difficulty. This range of operational scenarios varied in casualty loads, mission duration, and AE crew manning to provide an assessment of the operational effectiveness of an AMCL under various conditions of interest. These AE missions include both tactical/theater and strategic missions.

Wartime

• USAF Airbase #1 USAFE Tactical Fighter Wing	*AE Mission #1 *AE Mission #2 *AE Mission #3 *AE Mission #4	2E to 3E 2E to 4E 2E to 3E 2E to 3E	C-130 C-130 C-130 C-130
• USAF Airbase #2 USAFE Tactical Fighter Wing	*AE Mission #3	2E to 3E	C-130
• USAF Airbase/Installation #3 USAFE 3E Hospital	*AE Mission #5	3E to 4E	C-130
• USAF Airbase/Installation #4 USAF 4E Hospital	*AE Mission #6 CRAF 767	4E to CONUS	
• USAF Airbase #5	AE Mission #7	Base to 4E	C-130
• USAF "Barebase" Tactical Air Command (TAC) Unit	*AE Mission #8	Barebase to Hospital	C-141

Peacetime

• Routine C-9A Multistop	*AE Mission #9	Three Stops to Regional Hospital	C-9A
• Overseas Disaster Relief	*AE Mission #10 AE Mission #11		C-141 Evacuation C-130 Evacuation

A review of the scenarios relevant to the conclusions of the analysis as agreed to at the AMCL MRR is presented. The AE missions evaluated are marked with an asterisk (*).

USAF Airbase #1

- Description: A USAF tactical airbase with an assigned tactical fighter wing, air-to-ground/ground attack mission with associated support units. Base population is 5000. Facilities include semihardened and hardened facilities. Due to location and tactical situations, the evacuation of casualties will require aeromedical evacuation from base level 2E to a 3E MTF or 4E MTF as required.

- Attack Profile: Over a 24-hour period, Airbase #1 experiences a heavy enemy attack by aircraft [bombs, rockets, cannon fire, air-to-surface guided missiles, and cluster bomb units (CBUs) releasing bomblets and mines], by medium range ballistic missiles, and by Spetznaz units. The combined heavy attack includes chemical weapons, but not nuclear weapons. This is a severe attack with overall heavy casualties.

- Casualties:

Killed in Action	50		
Missing in Action	25		
Wounded in Action	248		
Disease, Nonbattle Injury (DNBI)	297		
Total	620		
Actual Patients	545		
Battle Injuries	248	DNBI	297
Workplace to 1E Died	50		0
Died	0		
Returned to Duty	3		3
	53		294
Moved to 2E	195	(Total 489)	294
Died	10		0
Returned to Duty	16		235
Patients to be Evacuated	169		59

Total - 228 casualties (160 litter, 68 ambulatory)

[10% suspected chemical warfare (CW) - 23]
(90% nonchemical - 205)

- Evacuation Profile: Over 24 hours post-attack, all 228 casualties are processed through a MASF into tactical AE missions as follows:

			Total	Casualty Breakout
a)	AE Mission #1	C-130	70	70 litters
b)	AE Mission #2	C-130	55	40 litters 15 ambulatory
c)	AE Mission #3	C-130	35	20 litters 15 ambulatory
d)	AE Mission #4	C-130	68	30 litters 38 ambulatory
		Total	228	

AE Mission #1 - Code Name "HEROIC"

- Mission Profile: 1 1/2-hour estimated time enroute (ETE) flying time from Airbase #1 to a 3E MTF airbase. Two full AE crews are assigned (ten total - four flight nurses and six aeromedical technicians).

- Casualty Load 70 Litters: All casualties are nonexpectant and are immediate or delayed triage categories, no minimals. As this is the first AE load after the attack, these are the most critical time-sensitive casualties who need priority medical and surgical care.

- Description of Casualties (70 litter): Ten chemical casualties (all eye and respiratory patients who are decontaminated, no liquid agent, no casualty wraps), three of ten are on respirators when boarded.

  a) Forty MFWs, 25 extremities, 6 head/neck, and 9 chest/abdomen.

  b) Ten burns plus other injuries.

  c) Five open/closed fractures extremities and/or crush wounds.

  d) Five concussive effects head/chest/abdomen.

- Aeromedical In-Flight Events:

  -- At takeoff (T/O) + 20 Minutes: One casualty goes into cardiopulmonary arrest and dies. One CW casualty not on respirator goes into respiratory distress and is put on respirator with standard settings.

  -- At T/O + 40 Minutes: One casualty becomes unconscious and is placed on respirator. If time permits, all respirator patients are given AMCL blood gas test to check for respirator effectiveness. If required, changes in respirator settings are based on AMCL blood gas test.

- Medical Summary: All CW patients will require intensive monitoring for respiratory condition. Give AMCL blood gas test if time permits. If time permits, patients with chest wounds can also have AMCL blood gas test to evaluate respirator condition. Hematocrit and electrolytes not required in a 1 1/2-hour mission.

Due to the heavy to heroic workload, the AE crew's strategy for primary treatment and care is through expert observation and by monitoring equipment. The AMCL blood gas test is medically useful for casualty care, but due to the 1 1/2-hour mission duration, it is secondary to expert observation.

AE Mission #2 - Code Name "TAC HARDWORK"

- Mission Profile: 3 1/2 hours of flight time from Airbase #1 direct to a 4E MTF. Two AE crews are assigned (total of ten).

- Casualty load 55: Forty litters and 15 ambulatory.

- Description of Casualties:

  a) Thirteen CW casualties (five litter, eight ambulatory), two are on respirators with no CW casualty wraps.

  b) Twenty MFWs, four chest/abdomen, three head, 13 extremities.

  c) Five burns.

  d) Five open/closed fractures/extremities/crush wounds.

  e) Seven ambulatory (three burns, four upper extremities).

- Aeromedical Flight Events:

  -- At T/O + 45 Minutes: One CW ambulatory casualty goes into respiratory distress and requires a litter and respirator. Using the AMCL blood gas test, adjust respirator settings on this new CW casualty and on the two boarded CW patients who are on respirators. If settings are changed, recheck respirator effectiveness via AMCL blood gas test 30 to 45 minutes later.

  -- T/O + 1 + 30: Mission now has three CW casualties on respirators. Recheck the effectiveness of respirator settings by using AMCL blood gas test. Adjust respirators as required, then recheck adjustments in 30 to 45 minutes. Check blood gases of the four chest injuries not on respirators by AMCL blood gas test to evaluate respiratory conditions and evaluate for respirators as required.

- Medical Summary: AE Mission #2 is 3 1/2 hours. With a slightly reduced casualty load, workload may permit more extensive medically effective use of blood gas tests to evaluate casualty care and treatment. A hematocrit test in a 3-hour mission is not required, but casualties with multiple bags of fluids and/or blood should be tested for hematocrit, if possible, before AE mission to baseline their status. The same is true with electrolytes on the burn casualties. Occult blood and CSF test can be performed for Categories II and III patient data requirements (later and long-term treatment). Neither test should affect treatment/care decisions in flight. Blood glucose test can be performed as required by medical circumstances for in-flight care and patient data requirements.

AE Mission #3: Code Name "TAC MULTIPLE STOP"

- Mission Profile: C-130 mission of 6 1/2 hours enroute from Airbase #1 to Airbase #2 to pick up additional casualties, then to Airbase #3 to a 3E MTF. Breakout of profile is ETE

Airbase #1 to Airbase #2 - 2 hours, 1 1/2-hour ground time; then from Airbase #2 to Airbase #3, 3 hours.

- Casualty Load:

Airbase #1 to Airbase #2		20 litters
		15 ambulatory
	Subtotal	35
Airbase #2 to Airbase #3/3E MTF		18 litters
	Total	53
		(38 litters and 15 ambulatory)

- Description of Casualties: First leg of mission, 20 litter casualties and 15 ambulatory, includes:

Twenty litter casualties as follows:

a) Ten MFW - 2 head/neck, 6 extremities, 2 chest/abdomen.
b) Two burn patients.
c) Four extremities fractures/crush injuries.
d) Four closed/head/chest/abdomen.

Fifteen ambulatories as follows:

a) Five extremities.
b) Five psychological.
c) Three MFWs (eyes/hands).
d) Two minors.

Second leg of mission, 18 litter casualties:

a) Nine MFWs.
b) Two closed concussive.
c) Five burns.
d) One dehydration.
e) One extremity crushed.

No chemical warfare casualties.

- Aeromedical Flight Events: Leg #1, two litters with chest injuries from Airbase #1 are on respirators.

-- T/O + 45 Minutes: Recommend that AE crew perform an AMCL blood gas test on two litters with respirators to confirm respirator settings. If necessary, adjust respirator settings based on test results, and recheck via blood gas test at 45 minutes elapsed time.

-- T/O + 1 Hour: One other chest wound goes into respiratory distress. This casualty is placed on a respirator and the respirator settings are checked via AMCL gas test in 15 minutes. The respirator settings are adjusted as necessary and rechecked over 45-minute intervals until casualty is stabilized.

-- T/O + 1 + 30: Two burn casualties have had significant fluid administration since injuries occurred. AE medical crews should check electrolytes via an AMCL test at

1 + 30 just before landing at Airbase #2, so additional fluids in quantity and type can be supplied at Airbase #2 as required.

-- T/O + 1 + 30: Two MFW litter casualties have received significant quantities of blood and fluids. The AE medical crew should check hematocrit with an AMCL test at 1 + 30 just before landing to see if blood resupply requirements need to be met at Airbase #2.

-- Landing at Airbase #2: It is recommended that all casualties on respirators or with identified chest wounds be given blood gas AMCL test to confirm their status/stability prior to departure on next leg of this AE mission.

Leg #2 - Takeoff from Airbase #2 enroute to 3rd Echelon MTF. Events enroute include:

a) Heart Attack (Myocardial Infarction): No AMCL requirement.

b) Blood Gases: AE medical crews should check all respiratory distressed casualties at takeoff plus 1 hour. If the casualties are stable, no additional blood gas tests are required. If respirators are reset due to blood gas test results, then recheck at 45 minutes. Those casualties who had severe wounds and chest wounds should be checked by AMCL hematocrit test at takeoff plus 30 to 45 minutes to evaluate the need to provide blood and/or fluids. The same is true for the burn casualties in relation to performing an AMCL electrolyte test at T/O plus 1 hour for specific fluid administration decisions. CSF test should be performed on leaking head wounds for Category II patient data requirements (later treatment). The same is true for occult blood test on two patients who vomit in-flight. No treatment decision in-flight on outcome of tests for CSF or occult blood, but these test results are very useful for Category II patient data requirement (later treatment decisions).

- Medical Summary: AE Mission #3 demonstrates that tactical missions longer than 1-3 hours have reasonable medical rationale for an AMCL if workload permits. In this operational scenario of a multileg 6 1/2-hour mission, blood gas determination will have an emergency treatment and preventive treatment benefit to those casualties who are in respiratory distress, develop respiratory distress in flight, or who have chest wounds where proper respiration can be impaired. Hematocrit and electrolytes are now effective tests due to the lengthy period of time involved with burn casualties and MFW casualties where significant amounts of blood and/or fluids have been given and are being given. The lab tests given just prior to transfer into the AE system become less reliable for treatment care decisions as time passes. Good medical care indicates that both hematocrit and electrolytes can be effective AMCL lab tests on longer missions if casualties' medical conditions dictate. The CSF and occult blood tests are very useful information for the next attending physician, but will not impact in-flight care and treatment decisions. Blood glucose can be used if the medical situation dictates and can affect the treatment and care decision, but even on 6-hour missions, this is not normally a critical treatment problem.

USAF Airbase #2

- Description: A USAF tactical airbase, communication center, logistics support base. Base population is 7,000; facilities include semihardened and hardened shelters. Due to the base location and tactical situation, a majority of the casualties can be moved by ground transportation; however, the base can support tactical AE of casualties as required.

- Attack Profile: Over a 24-hour period, Airbase #2 experiences light to medium attacks using bombs, rockets, air-to-surface missiles, cannon fire, CBUs with bomblets and

mines, by surface-to-surface missiles and by Spetznaz command units using small arms and mortars. No chemical or biological warfare attacks have been detected. This is considered a light to medium attack.

- Casualties:

Killed in Action	67
Missing in Action	4
Wounded/Injured In Action	271
Nonbattle Injury and Illness	135
Total Casualties into Base Medical System (Over 24 to 36 Hours)	406
406 Casualties at 1E: Returned to Duty	33
Killed in Action (Died in 1E)	2
371 Casualties in Triage-2E Medical Facilities: Returned to Duty	82
Killed in Action (Died in 2E)	2
Casualties Requiring Evacuation to 3E/4E Facilities	287

- Evacuation Profile: Of the 287 casualties requiring evacuation to a 3E MTF, 269 are transported by ground transportation, while 18 are evacuated by tactical AE on AE Mission #3, second leg, as described earlier.

USAF Installation/Airbase #3

- Description: A USAF 3E MTF near a servicing airbase capable of AE missions. The AE mission is to move casualties from the 3E MTF through an ASF to a 4E MTF using tactical AE aircraft.

AE Mission #5, Code Name "TO 4E"

- Mission Profile: A 3-hour C-130 AE mission from an airbase near the 3E MTF to an airbase near the 4E MTF. Two full AE crews are assigned. Casualties may not be fully stabilized, but most will have had stabilization care, removing some of the casualty status uncertainty. Casualty medical records, 3E clinical laboratory results, and physician treatment/care directions accompany the casualties.

- Casualty Load: Sixty, made up as 40 litter and 20 ambulatory casualties.

- Description of Casualty Load:

  Forty litter casualties as follows:

  a) Ten chemical warfare, plus other injuries, four of whom are on respirators.
  b) Twelve post-operative with chest/abdomen wounds.
  c) Six burn casualties.
  d) Five fractures of extremities with splints or casts.
  e) Five head/eye injuries.
  f) Two medical, one heart, one other.

Twenty ambulatory casualties as follows:

a) Fifteen treated MFW extremities.
b) Two eye injuries.
c) Two burns on arms/hands/upper body.
d) One medical.

- Estimated workload on the AE crew for this mission is medium to heavy.

- Aeromedical In-Flight Events:

  -- At T/O + 30 Minutes: A CW casualty goes into respiratory distress and requires a respirator. Thirty minutes later, the AE medical crew will perform a blood gas AMCL test to check for respirator effectiveness; adjust respirator settings as required; and then recheck blood gases 30 to 45 minutes later for respirator settings.

  -- At T/O + 1 Hour: Clear fluid is noted leaking from the ear canal of one casualty. An AMCL CSF test is performed for Category II or III patient data requirement (later and long-term treatment data). No in-flight treatment decision based on this test.

  -- At T/O + 1 + 30: One casualty appears pale and weak. A blood glucose AMCL detects low blood sugar. Treatment is administered to casualty based on this test.

  -- At T/O + 1 + 30: Two CW casualties on respirators are given blood gas AMCL tests as ordered by the 3E MTF physician in the casualty medical records to check on respirator effectiveness. Minor changes in respirator settings are made based on AMCL blood gas test results.

  -- At T/O plus 2 + 00: Two casualties vomit, and AMCL occult blood tests are given. No treatment decision is made, but test results are recorded for Category II and III casualty data requirements (later and long-term treatment decisions). One burn casualty is given an AMCL electrolyte test to monitor fluid status, as per physician boarding instructions. No in-flight treatment decision is required if test results are within subscribed limits, but results are entered in casualty medical records as a Category II or Category III (later and long-term) casualty data requirements.

- Medical Summary: Blood gas tests will be needed only for emergency treatment conditions, as the casualties will have been much more stabilized and medical trends established. However, the AMCL capability on board this mission enables an earlier evacuation decision by the physician, freeing up needed bed space at the 3E MTF. Hematocrit and electrolyte AMCL tests will not normally be required on this 3-hour mission; 3E clinical lab tests on these areas can be performed just prior to evacuation. These data should normally be sufficient for the casualty to be safely moved to the 4E MTF. Again, an earlier decision to evacuate can be made, knowing these AMCL tests are available. The CSF, occult blood, and glucose tests normally will not influence treatment decisions in flight, but will provide a safety margin for an earlier decision to evacuate to 4E MTF; Category II and III casualty data requirements can then be met in flight.

<u>USAF Installation #4</u>

- Description: A 4E MTF and nearby airbase to handle incoming tactical AE mission and outgoing strategic AE mission to CONUS. Additionally, an ASF is to service the missions. The AE mission is to move casualties from this 4E MTF through the ASF to a CONUS MTF using strategic AE aircraft.

AE Mission #6, Code Name "GOING HOME"

- Mission Profile: A strategic AE mission using a CRAF 767 from the airbase near the 4E MTF to an airbase near a CONUS MTF. Two full AE crews are assigned to this mission. Mission duration is 10 hours. Casualties are deemed reasonably stable for the 24-hour bed-to-bed evacuation policy criteria removing much medical uncertainty. Casualty treatment/ care directions by physicians come on board with definitive casualty medical records. Specialized medical supplies, such as casualty specific blood and fluids as well as respirators, are supplied for this mission.

- Casualty Load: 120 casualties made up as 90 litter and 30 ambulatory.

- Description of Casualty Load:

  Ninety litter casualties as follows:

  a) Twenty CW plus other injuries, six are on respirators.
  b) Thirty post operative chest/abdomen. One on respirator and physiological monitor, three on insulin profiles, three on cardiac monitors.
  c) Fifteen burns, plus other injuries.
  d) Twelve extremity fractures.
  e) Twelve head/eye injuries.
  f) One MFW plus other injuries on a respirator and physiological monitor.

  Thirty ambulatory as follows:

  a) Fifteen upper body extremities injuries.
  b) Five medical.
  c) Five eye injuries.
  d) Five psychological.

- Estimated workload assessment on AE crews is medium to heavy workload.

- Aeromedical In-Flight Events:

  -- T/O + 2 Hours: One burn casualty who is not on a respirator goes into emergency respiratory failure. This casualty is put on a respirator. Within 30 to 45 minutes, this casualty is given an AMCL blood gas test to determine respiratory condition and respirator setting effectiveness. Respirator is reset as required, and casualty is given another blood gas check 1 to 2 hours later to confirm respirator effectiveness.

  -- T/O + 4 Hours or on Physician Boarding Medical Orders: Perform a routine AMCL blood gas test on all casualties on respirators to evaluate respirator effectiveness.

  -- T/O + 4: One MFW casualty goes into unstable Disseminating Intravascular Coagulopathy (DIC). Perform a hematocrit AMCL test and administer blood as required. Perform glucose AMCL test on post-operative casualties or insulin profiles on a 4-hour sliding scale from last glucose clinical laboratory test.

  -- T/O + 6: Perform AMCL electrolyte test at 8-hour intervals, starting with time of last 4E clinical lab test. The burn patients with a history of significant fluid administration probably will have boarding instructions to perform AMCL electrolyte tests to monitor their status; record results for Category II and III patient data requirements.

- General Requirement: Perform AMCL occult blood and CSF test as required for casualties who vomit (or other body fluids as required) or have leaking head wounds (nasal or ear passages). These tests are for Category II and III (later or long-term) casualty data requirements.

- Medical Summary: A long strategic AE mission will benefit greatly from an AMCL capability due to the combination of mission duration and types of casualties on board. The AMCL capability will enhance an earlier decision to evacuate casualties to the CONUS, making available critical wartime theater bed space, improving morale of the casualties, and providing long-term care and administration of these casualties. The AMCL blood gas, hematocrit, electrolyte, and blood glucose tests all have direct medical immediate treatment and care decision needs and requirements, while the occult blood, CSF, and even possibly PTT, will influence Category II and III (later and long-term) casualty treatment decisions. The ability to get biological samples for the AMCL tests is somewhat better in the strategic AE mission rather than the tactical AE mission, but is still more restricted than the hospital setting.

USAF Airbase #6

- Description: A USAF-deployed unit operating barebase for a limited action, nondeclared war engagement. Two tactical fighter squadrons plus communications, logistics, security, and medical units are deployed. The medical unit is a 100-bed Air Transportable Hospital (ATH). Total base population is 1250 personnel.

- Attack profile: Over 24 hours, Airbase #6 experiences ground attack by artillery, large rockets, sapper/commando units, and some regular ground forces using small arms, rocket propelled grenades (RPG), mortars, and some limited CW agents. Attack is light to medium, with light casualties.

- Casualties:

Killed in Action	7		
Missing in Action	5		
Wounded/Injured In Action	72		
Nonbattle Injury and Illness	85		
Total	169		
Actual Casualties (Total - KIA, MIA)	157		
Battle Injuries	72	Disease, Nonbattle Injury	85
Died at 1E	5		0
Returned to Duty	18		46
	49		39
Moved to Medical Facilities			
Total 88	49		39
Died	2		0
Returned to Duty	11		15
	36		24
Casualties to be Evacuated	60 (19 ambulatory, 41 litter)		

AE Mission #8, Code Name "OUT OF DODGE"

- Evacuation Profile: All 60 casualties are to be evacuated by C-141 directly to a USAF Regional Overseas Hospital. A C-141 aircraft is used for the AE mission. Mission duration is 6 1/2 hours. Two full AE crews are assigned.

- Description of Casualties: 60 Total (41 litter, 19 ambulatory)

  Forty-one litter as follows:

  a) Ten emergency stabilization surgical cases post-operative chest/abdomen. Two are on respirators and four on cardiac monitors.
  b) Eight burns.
  c) Eleven head/eye injuries.
  d) Seven extremities fractures/wounds.
  e) Five MFWs, 2 on respirators/monitors.

  Nineteen ambulatories as follows:

  a) Nine extremities wounds/fractures upper body.
  b) Five medical.
  c) Two psychological.
  d) Three head/eye injuries.

- Aeromedical In-Flight Events:

  -- T/O +1 Hour: Two casualties go into respiratory distress. They are put on respirators, and 30 to 45 minutes later are given AMCL blood gas tests to evaluate respirator effectiveness. They are rechecked with an AMCL blood gas test every 45 minutes until stabilized. Based on physician boarding medical orders, all other casualties on respirators are given AMCL blood gas tests to evaluate respiratory condition. If test results require respirator setting changes, then AMCL blood gas tests are repeated every 45 minutes to reevaluate casualty until the patient is stabilized.

  -- T/O + 2 + 30: Two MFW casualties go unstable. AMCL hematocrit tests are given and blood is administered based on these test results. One burn casualty is given an AMCL electrolyte test based on physician boarding medical orders. Appropriate fluids are administered based on test results.

  -- T/O + 4: All post-operative casualties are given glucose tests if time permits. These casualties are checked every 4 hours on a sliding scale from last clinical laboratory test performed.

  -- T/O + 5: Two casualties are tested for occult blood and CSF using AMCL tests. Test results data are recorded in medical records as a Category II or III data requirement (later or long-term).

- Medical Factors: The AMCL capability will enable earlier casualty evacuation from this barebase combat situation due to the improved casualty care and treatment decision capability on the AE aircraft. Overall care of casualties is improved by the AMCL capability for immediate, later, and long-term casualty care requirements.

Stateside (Peacetime) C-9A Aeromedical Mission

AE Mission #9, Code Name "NIGHTINGALE"

(Note: For purposes of this report, casualties are called patients in the peacetime environment.)

- Description: This is a routine C-9A multiple base preplanned mission to pick up patients from several USAF medical facilities in order to move them to a USAF Regional Hospital for medical care.

- AE Mission Profile: Starting at Airbase A with five patients, ETE is 1 + 30 to Airbase B where 10 patients are loaded in a 1-hour ground time. The ETE to Airbase C is 1 hour and five patients are loaded at Airbase C with a 1-hour ground time. The ETE from Airbase C to Airbase D serving the USAF Regional Hospital is 1 hour. Total ETE including ground time is 5 1/2 hours with a total patient load of 20 at the end (12 litter and 8 ambulatory).

- Description of Patients (20 total, 12 litter and 8 ambulatory, by mission leg):

  a) Leg #1, 5 total:

3 litter	2 ambulatory
1 fracture	2 medical
1 burn	
1 cardiac	

  b) Leg #2, 10 total:

5 litter	5 ambulatory
1 burn	3 medical
1 cardiac or monitor	1 eye
3 medical illness on fluids	1 upper extremity injury

  c) Leg #3, 5 total:

4 litter	1 ambulatory
2 medical	1 medical
2 fractures	

- Aeromedical In-Flight Events:

  Leg #1 and Leg #3 - no significant medical events.

  Leg #2, T/O + 30 Minutes: One litter patient on a cardiac monitor goes into respiratory distress. Patient is put on respirator and given AMCL blood gas test 15 minutes later to evaluate respirator effectiveness. Patient stabilizes and continues on mission.

- Medical Summary: In wartime conditions, an overriding decision is to evacuate as soon as possible to enable more definitive care and to free needed bed space at lower echelons of care. This sense of urgency is lacking somewhat in a peacetime C-9A normal AE mission. The absolute requirement for an AMCL can be reduced by the ability to make better decisions on stability prior to patient evacuation; by the ability to better preplan patient loads, associated medical equipment, AE crew size, including a physician if needed, and

detailed medical instructions for in-flight care; and by the ability to divert rapidly to handle emergency patient care events. However, medical expertise agreed that not every situation can be preplanned, and having an AMCL capability on board will enhance overall medical care for in-flight contingencies on C-9A evacuation missions. Some earlier evaluation decisions on critically ill or injured patients will be possible with an AMCL on board.

Overseas Disaster Relief

- Description: There has been a major natural disaster in an overseas friendly country. The U.S. decides to provide major relief and medical support for emergency medical care. The operations plan calls for the use of USAF aircraft to evacuate non-English speaking patients from the disaster site to an overseas civilian airfield near a major civilian medical center. C-130 and C-141 aircraft will move patients via an MASF setup near a deployed Air Transportable Hospital that is used for triage, emergency treatment, and surgical stabilization as required.

AE Mission #10 C-141

- Mission profile: A 2-hour mission with 90 non-English speaking patients on board. Two full AE crews are assigned, plus two USAF physicians.

- Description of 90 Patients (50 litter and 40 ambulatory):

  Fifty litter as follows:

  a) Thirty fractures.
  b) Ten burn, plus other injuries.
  c) Ten medical illness.

  Forty ambulatory as follows:

  a) Fifteen head/eye injuries.
  b) Ten upper extremities.
  c) Fifteen medical illness.

- The AE crew workload is estimated to be very heavy.

- Aeromedical In-Flight Events: In this set of circumstances, the use of an AMCL will be extended into the ground based MTF and MASF as well as in the aircraft.

  -- T/O + 30 Minutes: AMCL blood glucose tests are given to nine patients who become unstable for unknown reasons.

  -- T/O + 1 Hour: Several patients have respiratory distress and are placed on respirators based on personal expert medical observation. Due to workload conditions and probable patient fear of taking samples, blood gas tests normally will not be performed unless absolutely necessary. Probability of patient survival using preselected respirator settings over the 2-hour ETE is good, reducing the need for definitive blood gas test results.

- Medical Summary: An AMCL will have significant operational use in this environment, both for ground-based and aircraft medical assets. It appears that blood type and crossmatch, hematocrit, and electrolytes will be needed in the ground medical units and probably not in flight, due to the short 2- to 3-hour missions. Blood glucose and blood gases poten-

tially will be very useful tests for in-flight care of patients during immediate care (Category I) patient data requirements for immediate treatment decisions. If AE missions last over 3 hours, then AMCL capability for the in-flight system should be considered.

SUMMARY OF FINDINGS AND CONCLUSIONS

The assumption for casualty data requirements was presented in order of priority in Section 3 and was as follows:

- Category I: Data needed to make an immediate treatment decision.
- Category II: Data needed that may influence later treatment decisions.
- Category III: Data needed for long-term care and administration of casualties.

The data for these categories of casualty care decisions are as follows:

- Expert Personal Observation
- Physiological/Medical Monitoring
- Clinical Laboratory Data

In the last set, Clinical Laboratory Data, the AMCL would fit as a major category of data input for casualty care decisions in an AE environment. The set of factors important to evaluate the effectiveness of an AMCL was determined to be as follows:

- Need the Data for a Treatment Decision
- The Therapeutic Alternative is There to Implement the Treatment Decision
- Staff/Skill/Time are Available

Need the Data for a Treatment Decision

As shown in Figure 3, the integrated set of relevant casualty data comes from:

- Expert Personal Observation by Medically Trained Personnel: In the AE mission environment, trained personnel usually means flight nurses and/or AE technicians. Although medical observation by these skilled personnel is important, it can be safely stated that it will not be as good as observation by a trained physician. It also will be degraded somewhat by the AE aircraft environment of confined space, poor lighting, bandages, etc., and the condition of the casualty. Certainly a CW casualty wrap will make personal observation a most difficult diagnostic test. More weight generally can then be given to physiological/medical monitors and clinical lab results under certain environmental and assigned crew conditions. Again, this is not to degrade the importance of the vital medical input of expert personal observations, but to share it in context with other medical casualty data sources.

- Physiological/Medical Monitors: This is a valuable set of casualty data, but restricted in completeness in the range of specific medical conditions it covers. The use of physiological monitors in the AE environment is also sometimes difficult due to density of casualty loads and available time to monitor the information. The use of this data source is a multiplier if it can be combined with personal observation and clinical lab data.

- Clinical Laboratory Data: Provide excellent data on the tests' specific applicable conditions of the casualty and are relatively current. Coupled with personal observation and physiological monitors, it can provide vital data for immediate treatment decisions. It also can confirm the accuracy of treatment decisions based on other factors. Certainly a casualty

who is observed to go into respiratory distress and has abnormal physiological monitor inputs can be put on a respirator based on these two inputs alone. However, the need to confirm the effectiveness of the respirator in terms of frequency, tidal volume, and percent of oxygen can only be made accurately with some blood gas data. Clinical lab tests for hematocrit and electrolytes will show vital abnormal results for treatment decisions before abnormalities are visually observed or are displayed on physiological monitors. Chemical lab tests mean overall improvement in the opportunity to increase casualty care and possibly survival in the AE environment.

Therapeutic Alternatives are There to Implement the Treatment Decision

Obviously, there is little need to do an electrolyte test on a casualty if the treatment decision based on this test result is specific fluid administration and no such fluids are available. The same is true for a hematocrit test or even a blood gas test. As the priority need for this information in an AE environment is to impact immediate treatment decisions, this factor is very important. The medical treatment method and supplies should be available to implement the treatment decision based on a test result. If the test is to create patient data for a later or long-term treatment, care and administration of the casualty, then the appropriate test can be performed and the data properly recorded if the AE crewmember's time is available to perform the test.

Staff/Skill/Time are Available to Do These Things

This factor is an important one for both pro and con discussion of the utility of an AMCL in an AE environment. The items affecting availability are the mission environment, mission length, type of aircraft, load and condition of casualties, numbers of AE crewmembers on board (ratio of crew to casualty), workload factors, AE crew training and experience (especially in taking necessary samples for AMCL tests and reading and interpreting test results, etc.), and medical equipment and supplies on board. If several casualties require treatment at the same time, the head of the AE medical crew must decide if the time and staff are available for AMCL type tests and in what priority. This decision holds true for any emergency medical care situation; however, the conclusion reached is that it should not limit the equipment or testing methodologies that could be used for the best casualty care possible if the skill, staff, and time are available.

Summary of Factors Influencing the Utility of an AMCL

The following factors will influence the utility of an AMCL:

a) Type of aeromedical aircraft used (i.e., C-130, C-141, C-9A, CRAF 767, MD-80).
b) Type of mission flown (tactical, strategic, peacetime, wartime).
c) Mission duration/ETE.
d) Numbers, conditions and stability of casualties on board.
e) Numbers of AE crewmembers on board, including nurses, medical technicians, and physicians.
f) Workload conditions/factors for the AE crewmembers.
g) Medical treatment equipment and supplies available.
h) Types, numbers, and methods of collecting necessary AMCL samples.
i) Need for the AMCL generated data for a treatment decision (Category I, II, or III patient data requirements).
j) Can the AMCL generated casualty data be properly recorded?
k) Will the treatment decision improve casualty care, treatment, survival, and administration?

All of these analyses and factors will impact the AMCL preliminary design criteria found in Section 5.

Conclusion

The conclusion reached after completion of the mission analysis as presented so far in this report and as agreed to by the contractor teams, AMCLWG, and the representatives at the AMCL MRR, is that the concept of an in-flight field portable laboratory is valid and should be further developed as a technological option. The AMCL will enhance the effectiveness of the USAF AE mission by improving the opportunity for better survival, care, and treatment of casualties and patients who enter the system. Certainly, the AMCL system must be carefully designed, tested and validated before becoming operational, but there remain numerous issues to be resolved. The next step will be to evaluate the current state of clinical laboratory equipment and technology to an AMCL as presented in Section 6. The next recommended technology step is to develop a specification for the development of an AMCL for feasibility testing and evaluation.

Section 5

AMCL PRELIMINARY DESIGN CRITERIA

Based on the results of the analysis and the factors concerning the utility of an AMCL as presented in Section 4, the contractor team and AMCLWG arrived at the following preliminary design criteria for an AMCL. The preliminary design criteria were used as a starting point by the University of Texas at San Antonio in their literature and technology survey and systems design analysis. The preliminary design criteria presented in this report were reviewed and accepted by the AMCL MRR.

AMCL PERFORMANCE

The performance preliminary design parameters for an AMCL were as follows:

- Tactical AE mission, short flight, 0 to 3 hours.
- Tactical AE mission, long flight, 3 to 8 hours.
- Strategic AE mission, up to 24 hours bed-to-bed for the casualty.
- Wartime versus peacetime conditions are a design consideration due to types of casualties/ patients which the AE system will handle.
- Stateside versus overseas conditions are a design consideration because stateside missions usually can divert to handle casualty/patient emergencies more readily than overseas missions.

Recommended AMCL Diagnostic Tests

- Blood Gases
- Hematocrit
- Electrolytes
- Blood Glucose
- CSF
- Occult Blood

PTT and BUN were considered and discussed; cost/difficulty factors should be evaluated in the final AMCL specification.

AMCL Test Data Standards

The following are needed:

- Have direct readout capability.
- Have direct recording capability for records purposes with little action by AMCL operator.
- Be casualty/patient specific.
- Be automatic as possible, i.e., put in sample, test, get readout results.
- Be accurate.
- Be simple to read by AE crewmembers.
- Be available through a standard computer port.

AMCL TEST SAMPLES

A problem with a clinical laboratory on board an AE aircraft is taking, handling, storing, controlling, and disposing of samples for the test in this environment. The preliminary design criteria for samples are as follows:

- Noninvasive is the preferred method of testing whenever possible.
- If invasive samples are required, the sample size should be as small as possible.
- The sampling technique should be uncomplicated; it should not compromise safety for both the casualty/patient and the AE crewmember.

AMCL PHYSICAL PROPERTIES PRELIMINARY DESIGN CRITERIA

The following AMCL physical properties were based on the mission analysis, AMCLWG inputs, and the MRR.

Size and Weight

The AMCL dimensions should not exceed two litter spaces. The AMCL should not exceed the maximum weight and portability considerations for AE litter supports. AE crewmembers are expected to carry the AMCL on board the aircraft and install it in the aircraft.

Durability/Vulnerability/Environmental Factors

The AMCL should be able to withstand normal handling and stress in the operational environment of intended use, including normal ground and in-flight handling without damaging or degrading the equipment's capabilities. The AMCL shall be safe to operate in the aircraft environment. It shall resist the forces of electromagnetic interference (EMI), impact, and vibration, as well as the hazards of chemical exposure, vapors, flammables, explosives, and pyrotechnics. The AMCL must operate in unfavorable environmental conditions of temperature, dust, humidity, rain, snow, wind, etc.

AMCL Calibration Factors

Calibration of the AMCL should be uncomplicated without requiring special equipment. Calibration should not be affected by unfavorable mission conditions. Ideally, the AMCL should not require recalibration once installed for an AE mission until that AE mission is complete. The AMCL should activate a visual or audible signal when calibration falls below tolerance levels.

AMCL Modular Concept

The AMCL should have modular components; selected modules can be used in flight without powering-up the whole system. The ability to centrally locate the AMCL on the aircraft with casualty/patient samples brought to this central location for processing must be traded off against taking the appropriate module to the casualty/patient site and performing the test there. This modular design should enable either operational methodology to be used for specific mission or casualty situations. The AMCL design must be compatible with all AE aircraft (C-9A, C-130, C-141, CRAF 767, and CRAF MD-80).

AMCL Power and Safety Criteria

The AMCL electrical specifications must be compatible with all AE mission aircraft. There should be a backup power system to prevent power interruptions or to maintain self-contained capability during stop-overs when aircraft power may be shut down or interrupted. The AMCL should not pose physical, electrical, fire, or chemical hazard to AE personnel, should not interfere with aircraft or ground equipment, and should be safe to operate.

Human Engineering and Training Criteria

The AMCL should be designed for human factors/engineering in the environment where it will be used in accordance with Military Standard (MIL-STD)-1472C and appropriate design handbooks. The training required to operate an AMCL shall be included in the Aeromedical Evacuation Technician and Flight Nurse Courses, in on-the-job training, and in recurring training levels. The AMCL shall be designed to be operated by one person. All certified AE crewmembers shall be AMCL qualified.

Maintenance/Logistics/Supply Criteria

The AMCL should be self-contained for operation with redundancy engineered in identified mission specific AMCL test capability. The unit should not require service, supply, recalibration, or maintenance during AE flight operations.

AMCL Reliability and Maintenance Criteria

The AMCL unit should not fail during any AE mission. It should have built-in redundancy to reduce the frequency of failure. No single test capability failure should totally disable the unit. The unit should be maintainable by USAF personnel, and not be required to be returned to the factory for recalibration, resupply, or normal maintenance.

SUMMARY

The AMCL preliminary design criteria presented in Section 5 are based on operational missions requirements analyses, casualty/patient data requirements, and associated diagnostic tests. These areas are amplified and detailed in Section 6, Systems Requirements Analysis.

Section 6

SYSTEMS REQUIREMENTS ANALYSIS

This section shall present a systems requirements analysis that includes the following:

- Literature and technology survey to determine the available equipment and technology to satisfy the operational requirements for the AMCL.

- Based on the above, take the preliminary design criteria as presented in Section 5, identify current and near-term equipment and technologies that may be used in an AMCL.

Expertise was gathered from many sources to conduct this analysis including systems analysts and aeromedical consultants from SRL; mechanical and electrical engineers and an aerospace physiologist from UTSA; and, most important, a dedicated group of USAF aeromedical nurses, technicians, and biomedical engineers. Each of these participants was essential to this study and the results are a testament to their efforts.

To compile this section, it was necessary to develop an understanding of the potential applications for clinical equipment as outlined in previous sections of this report. This new insight led to the designation of such equipment as being eligible for inclusion in an AMCL. Contractor team members visited USAF facilities in which currently available clinical laboratory equipment was employed and met with USAF and other clinical laboratory personnel. These visits were conducted: (1) to identify potential candidates from existing inventories; and (2) to discuss advantages, disadvantages, and limitations of the current equipment. The UTSA team also performed a detailed search of the clinical laboratory equipment market, technical journals, and national databases and interviewed technical representatives to determine other available equipment which could be used in an AMCL array. The contractor team conducted a patent search and reviewed technical journals to identify near-term technologies or new approaches to the acquisition of relevant diagnostic data. The aforementioned information was then used: (1) to develop a set of criteria for any equipment that might be selected for use in an AMCL array; (2) to evaluate the current equipment and near-term technologies against these criteria; and (3) to develop recommendations for assembling an AMCL array for potential use in both strategic and tactical aeromedical environments.

The diagnostic tests which served as the focus for this project were developed by the contractor teams, and approved by the USAF Technical Manager. These tests are summarized below:

- Arterial Blood Gases: Oxygen (PO_2), Carbon Dioxide (PCO_2), pH
- Plasma Electrolytes: Potassium (K), Sodium (Na)
- HCT
- Blood Glucose (GLU)
- Occult Blood (OCC)
- CSF
- PTT
- BUN

It should be noted that the primary medium required for these tests is blood. Other than the tests for occult blood and cerebrospinal fluid, obtaining a blood sample is essential for data acquisition. Within these blood-related tests, blood gases normally require obtaining a sample of arterial blood, whereas the others can be determined from a venous sample.

METHODS

The contractor team visited several sites to study the physical characteristics of the aeromedical environment and types of equipment that might be useful in an AMCL. These sites included aeromedical aircraft mock-ups at USAFSAM, Brooks AFB, TX. These mock-ups are used by USAFSAM to train physicians, nurses, and aeromedical evacuation technicians for aeromedical missions. The contractor team interviewed AE crewmembers assigned to conduct this training as well as others assigned to the Aeromedical Research Function at USAFSAM. These visits and interviews provided an understanding of the operational aspects of these missions and of the physical environment in which they are conducted. Subsequently, the team reviewed MIL-STDs and other relevant documents describing aeromedical environments and requirements for use of the equipment.

To identify clinical laboratory equipment currently in use in USAF medical facilities, the team visited several sites. These sites included the USAF Clinic at Brooks AFB, the clinical laboratory in the Clinical Sciences Division of USAFSAM, and the main clinical laboratory in the Wilford Hall USAF Medical Center at Lackland AFB, TX. In addition, the team interviewed clinical laboratory personnel at these sites to determine: (1) technical information on the available equipment; (2) potential advantages, disadvantages, and limitations for use in an AMCL; (3) criteria for selecting available equipment; and (4) skills required to operate and maintain this equipment. Finally, the contractor team visited with LCdr. Joseph White, a U.S. Navy clinical laboratory officer and a member of the DEPMEDS panel, assigned to the U.S. Army Academy of Health Sciences, Ft. Sam Houston, TX. He provided insight on the procedures other services use in selecting clinical laboratory equipment, on studies underway to standardize the equipment used throughout the DoD, and on equipment currently in use in other DoD clinical laboratory facilities.

The contractor team also conducted literature searches and patent surveys, reviewed technical journals, and interviewed medical equipment manufacturers and vendors to compile information about the current and near-term technologies that can provide data on the proposed diagnostic tests. Wherever possible, current clinical laboratory equipment was evaluated in a USAF clinical setting or through a demonstration of the equipment.

CLINICAL LABORATORY EQUIPMENT AND NEAR-TERM TECHNOLOGIES

Information obtained during site visits and interviews served as sources for contacts with vendors of currently available equipment. The contractor team also reviewed such compilations as the Thomas Register, Medical Devices Register, Health Devices Sourcebook, Emergency Care Research Institute (ECRI) Product Comparison Systems (PCS), and journals of laboratory equipment to identify other vendors of clinical laboratory equipment. The ECRI reports are of particular note because of their in-depth coverage of classes of equipment used in the health care industry. Several were obtained for use in this project and are included. Fifty-four vendors were contacted and requested to provide technical information. Data were received from 42 companies; from these companies, over 70 instruments were found which had possibilities for the AMCL concept. Several vendors volunteered to demonstrate their equipment. These demonstrations provided significant insight into the skills needed to operate and maintain this equipment, as well as technical details that might have impact on the selection of a device, in its current configuration, for use in an AMCL.

Information provided by the clinical laboratory personnel is included in Appendix A. Key findings are included in this section. These personnel indicated that there are no service-wide criteria or regulations for selection of this equipment. Instead, selection is based primarily on experience and preferences of clinical laboratory personnel with approval of price and availability of local servicing. Based on the findings of this study, it appears that this process of equipment selection is the norm throughout the USAF and other military services.

LCdr. White provided information on the time required for conducting clinical laboratory tests as published in the DEPMEDS guidelines. These times are listed in Appendix A. It should be noted that these times refer to the interval from obtaining the sample until it is ready for presentation to the measuring device and that the time for measuring cerebrospinal fluid is based on determining protein or sugar levels in this fluid.

A literature search identified other technologies and new approaches to obtain data for the proposed diagnostic tests. The search was performed through the UTSA library and focused on literature from engineering journals and other technical sources.

A patent search was conducted to identify any new technologies for the performance of these tests. Several patents were identified as being relevant. The technologies described in these patents were found to be already incorporated in currently available equipment.

A review of journals in the USAFSAM Strughold Aeromedical Library was also conducted to identify manufacturers of clinical laboratory equipment other than those identified during the site visits, interviews, and literature and patent searches.

Given information obtained on the physical characteristics of aeromedical environments (for example, aircraft vibration and patient locations) as well as human factors issues related to the aeromedical crews, it was apparent that diagnostic blood gas tests that require obtaining arterial blood samples will be a major limitation to the effective use of an AMCL. Accordingly, the UTSA team conducted interviews as well as literature and patent searches to determine the availability of equipment that could provide this information "noninvasively."

For the purposes of this report, two categories of equipment are discussed. The term invasive is used to refer to equipment that requires obtaining blood samples for processing and analysis. The term noninvasive refers to equipment that can provide data for these diagnostic tests based on information obtained by electronic or optical means through the patient's skin.

Data obtained on the invasive equipment from the above sources were assembled into an AMCL database for further review and analysis. Information on noninvasive equipment as well as other equipment identified in the future can be added to this database to enable the database to serve as a single repository. The database was developed using the CLIPS software. Details on the design of the AMCL database and an example of its content appears in Appendix B.

DETAILED DESIGN CRITERIA FOR AMCL EQUIPMENT

The initial preliminary design criteria for an AMCL was presented in Section 5. The details of the design criteria are presented in this section. Devices proposed for use in an AMCL must: (1) output patient status data on one or more of the proposed diagnostic tests; (2) operate in the aeromedical environment; (3) be operable by aeromedical personnel; and (4) not impose additional workload that exceeds the time available within existing aeromedical mission scenarios. Specific criteria for evaluation of candidate equipment were developed from the physical parameters of aeromedical environments and human factors issues related to the potential uses of an AMCL. These criteria were used to sort through the information provided on clinical laboratory equipment and enabled a recommended set of approaches that will provide the capability to conduct the proposed diagnostic tests within the aeromedical environment.

Blood glucose data can be obtained from several of the large clinical laboratory devices. However, it can also be obtained through the use of dedicated devices that perform only this test. These devices are small, easy to operate, and require minimal training. Chemstrips can also provide these

data and should be considered for use in an AMCL. However, these paper tests require color comparisons of the test paper with a standard color chart. The accuracy of this comparison may be significantly compromised in the spectrally unbalanced light levels found in several of the aeromedical aircraft (e.g., C-130) and in the ground-based barometric settings.

The most demanding task required for any of the proposed diagnostic tests is obtaining arterial blood samples. Even in the optimum hospital environment, only well-trained and proficient hospital staff can be expected to routinely obtain suitable samples. Under environmental conditions found in many of the aeromedical settings, the capability of even highly proficient technicians to routinely obtain suitable samples can be expected to be degraded. Further, arterial blood samples that will be used to measure blood gases and pH must be kept on ice if the time between drawing and analysis is likely to extend beyond a few minutes. Finally, interviews with clinical laboratory personnel indicated that these samples will only be suitable for measuring arterial gases and pH if this time interval is limited to 20 minutes or less. Therefore, skill requirements to obtain the sample as well as time constraints for accomplishing the tests impose significant burdens on personnel assigned this difficult task. Consequently, it is highly desirable that alternative means be found for assessing the arterial blood gases.

Electrical Power

The power available on aeromedical aircraft limits equipment use without electrical modifications. The variety of electrical power is demonstrated in Table 5.

TABLE 5. ELECTRICAL POWER AVAILABILITY

Aircraft	Voltage	Frequency	Source
C-141	110V	400 Hz	Engines/Generators
	28V	DC	Stepdown Transformer/Rectifier
	110V	60 Hz	Unitron Frequency Converter
C-130	110V	400 Hz	Engines/Generators
	28V	DC	Stepdown Transformer/Rectifier
	110V	60 Hz	Unitron Frequency Converter
C-9A	110V	400 Hz	Engines/Generators
	28V	DC	Stepdown Transformer/Rectifier
	110V	60 Hz	Engines/Generators
CRAF	110V	400 Hz	Engines/Generators
	28V	DC	Stepdown Transformer/Rectifier
	110V	60 Hz	Engines/Generators

The primary source of electrical power for all these aircraft is 110V/400 Hz produced by the engine's power which is then rectified and filtered to produce 28 VDC. The 110V/60 Hz is obtained from the portable Unitron Frequency Convertor. Due to its large size and weight, the unit is not easily maneuvered. It is of special importance that the 28 VDC power is used primarily to operate aircraft avionics, and is not likely to be available to operate AMCL equipment. Due to the wide range of power sources and the fact that temporary power surges and even disruptions are not unusual, the potential for selection of equipment for incorporation into an AMCL is greatly enhanced if the device operates on battery power. Even greater potential exists if these batteries could be recharged from the aircraft power systems.

Electromagnetic Interference

All electrically-operated equipment emits electromagnetic radiation during operation. If the electromagnetic radiation from the AMCL equipment is too strong, it could be a potential threat to other aircraft electrical equipment (for example, avionics), endangering all personnel on board. On the other hand, the electromagnetic radiation from other aircraft electronics could cause the AMCL devices to malfunction, which could result in inaccurate data output, temporary disruptions in performance, or permanent damage.

The term radiated emissions refers to the electromagnetic energy that equipment radiates. The term radiated susceptibility refers to the sensitivity of equipment to electromagnetic energy. Equipment is often connected to the aircraft's electrical system through wiring which can conduct undesired equipment-to-equipment communication causing equipment failures.

The term conducted emissions refers to the electrical "noise" transmitted by equipment via its power lines. The term conducted susceptibility refers to the sensitivity of equipment to this transmitted electrical noise. While the specific details of the ambient and allowable levels of this electrical noise for all of the USAF aeromedical aircraft was not available, all AMCL equipment must meet standards for emissions and susceptibility as set out in MIL-STD-461 (Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference, Category A1e). These standards define: (1) the maximum amount of electrical noise in aircraft environments; and (2) the maximum amount of electrical noise that electronic equipment can contribute to the aircraft environment. Specific tests for equipment under consideration for use in aeromedical aircraft are described in The Aeromedical Equipment Evaluation Laboratory Procedures Guide, Draft. These tests incorporate the requirements specified in MIL-STD-461.

Vibration

Equipment selected for use in an AMCL must survive and operate within an environment that imposes significant and quite variable physical vibrations. Although the AMCL would normally be in use while the aircraft is at cruising altitudes, it is likely that unexpected changes in altitude and attitude as well as the normal characteristics of landing and take-off flight profiles will create vibrations that could affect equipment electronics, reagents, and associated materials. Vibration curves (i.e., vibration amplitude versus frequency) that can be expected in the aeromedical environment are defined in MIL-STD-810. Some modifications to this information have been incorporated into The Aeromedical Equipment Evaluation Laboratory Procedures Guide, Draft.

Thermal Environment

Aeromedical missions are conducted under wide ranges of thermal conditions including extremes of temperature and relative humidity on the ground as well as during flight. Virtually all of the clinical laboratory equipment available today is designed for use in the relatively benign thermal environment of a medical facility. Neither the electronics nor the reagents are specifically designed for operation under the thermal extremes that can exist in aeromedical missions. In addition to the extremes likely for ground operations, loss of cabin integrity while in flight will result in rapid temperature drops to that prevailing at the flight altitude. While it is unlikely that the AMCL equipment will be used under these emergency conditions, survival of patients and later use of this equipment after such an event is essential. The ranges for thermal conditions are described in The Aeromedical Equipment Evaluation Laboratory Procedures Guide, Draft and are summarized in Table 6.

TABLE 6. TEMPERATURE AND RELATIVE HUMIDITY EXTREMES

Humidity:	94 ± 4 percent relative humidity at 85°F ± 3.6°F (29.5°C ± 2°C) for 4 hours
Hot Temperature Operation:	120°F ± 3.6°F (49°C ± 2°C) for 2 hours
Cold Temperature Operation:	32°F ± 3.6°F (0°C ± 2°C) for 2 hours
Hot Temperature Storage:	140°F ± 3.6°F (60°C ± 2°C) for 6 hours
Cold Temperature Storage:	-40°F ± 3.6°F (-40°C ± 2°C) for 6 hours

Operational Altitudes

Equipment selected for use in an AMCL must be expected to operate over a wide range of atmospheric pressure. Not only is there a need to withstand various pressures, but the rate of change is also an important factor. Whereas the cabin altitude for most aeromedical missions can be expected to remain below 10,000 feet, emergency conditions, including unexpected loss of cabin pressurization, may raise the cabin altitude equivalent to the flight altitude. The Aeromedical Equipment Evaluation Laboratory Procedures Guide, Draft contains information on the changes of atmospheric pressure. For purposes of this report, this information is presented in terms of environmental altitudes.

Operational Requirement: Operate accurately and indefinitely at 10,000 feet above sea level (barometric pressure, 522.8 mmHg).

Reliability Requirement 1: Ascend from the ground to 8,000 feet, at a minimum of 500 feet/minute, equipment must operate; decompress to 40,000 feet in 60 seconds with equipment operating; return to 8,000 feet and equipment still operates.

Reliability Requirement 2: Ascend from the ground to 8,000 feet at a minimum of 500 feet/minute, equipment must operate; decompress to 40,000 feet in 7 seconds with equipment operating; return to 8,000 feet and equipment still operates.

Reliability Requirement 3: Ascend from the ground to 8,000 feet at a minimum of 500 feet/minute, equipment must operate; decompress to 40,000 feet in 1 second with equipment operating; return to 8,000 feet and equipment still operates.

Luminance

The C-130 and C-141 aircraft are used primarily to transport cargo and passengers. Consequently, these aircraft are not equipped with interior lighting comparable to aircraft that routinely carry personnel who must perform significantly demanding visual tasks while in flight. When these aircraft are reconfigured for aeromedical missions, there are no provisions to enhance existing lighting conditions. As a result, aeromedical personnel often resort to portable light sources. The C-9A and the aircraft assigned to the CRAF have more acceptable light levels because the C-9A is designed specifically to transport patients, and the CRAF is a converted civilian passenger aircraft. Much of the equipment available for use in an AMCL provides digital data output displayed in a variety of ways, including light emitting diodes (LED), green phosphor screens, and liquid crystal display (LCD). The value of devices that use LCD for data is very limited in an aeromedical environment because this type of display requires relatively high levels of ambient light. The available light in aeromedical aircraft (e.g., C-130) and the ground-based aero-

medical settings will compromise the use of these devices. The correct interpretation of instructions on the equipment face and the details on gauges, dials, and switches will also be compromised by this inadequate lighting.

Audible Noise Level

In addition to the prevailing light conditions, cabin noise levels differ significantly in the C-130 and C-141 and from those found on the C-9A and CRAF. The effectiveness of equipment that produce audible signals related to calibration, stability, and test status can be expected to be compromised in these high noise environments. Alternative means for signaling equipment status (for example, flashing lights) will be needed for effective use in the aeromedical environment.

Space and Mobility

Space is limited on aircraft used for aeromedical missions. Given the nature of these missions, highest priority is given to patients and life saving/sustaining equipment. Further, the differences in patient loads and aircraft-specific litter and seating arrangements dictate a wide variety of cabin configurations. Of necessity, equipment selected for use in an AMCL must be compatible with these variables. Visits to the aeromedical equipment mock-ups revealed variations in the manner in which litters are secured while in flight. The C-141 has a litter stanchion resembling a ladder for one side of the litter while the other is suspended from a fabric belt. In the C-9A, litters are supported on arms that extend out from the cabin wall. Flexibility in locating the AMCL will be important to enabling its use in different aeromedical missions. It is critical that potential locations and mechanisms for securing AMCLs be proposed and investigated. The selection of equipment for the AMCL will depend on its compatibility with these options. Examples of the considerations that must be made include possible location of an AMCL on a litter or passenger seat. The litter location would provide a setup that could be loaded, unloaded, and moved about the aircraft during flight. Should AMCL equipment intended for monitoring a single patient be selected, prepositioning these units on a litter prior to use would still afford easier loading/unloading. For those devices intended for individual monitoring, attachment to the patient's litter or nearby litter stanchions/belts is an option.

Human Factors

The number of personnel and their aeromedical training and experience varies significantly. Common to all is the presence of nurses and medical technicians with specific training in the care of patients while on board aircraft. This training may include drawing arterial blood samples. However, the experience of these personnel to perform their tasks in these environments can be expected to vary significantly. The tasks assigned to these personnel will be similar as they relate to direct patient care; however, the overall responsibility for the patients and decisions on medical interventions are generally borne by the nurses. Workload of these personnel before, during, and after each mission will vary greatly. Tactical missions can be expected to be shorter, but the flight profile as well as patients' status and stability will impose a significant demand on the entire aeromedical crew. Strategic missions, on the other hand, will be longer, have more patients (and presumably crews), but could still impose similar demands on the individual personnel. It is possible that neither the nurses nor the technicians have had significant experience in using clinical laboratory equipment. Even more remote is the possibility that these personnel would have had training in the calibration, maintenance, and servicing of such equipment. It will be essential to determine the skills and time factors associated with: (1) acquisition of the required biological samples; (2) use of the clinical laboratory equipment; (3) data acquisition; and (4) data recording.

Criteria for Evaluation of Candidate Equipment

The aforementioned physical characteristics of the aeromedical environment and human factors issues were integrated into a set of criteria used to evaluate the clinical laboratory equipment and near-term technologies. The following sections describe the invasive and noninvasive equipment relative to these criteria. It is readily apparent that there are many criteria for which information is unavailable, which was not unexpected, given that the equipment was not originally designed for use in an aeromedical environment.

INVASIVE EQUIPMENT

Virtually all of the clinical laboratory equipment identified in this project require obtaining a biological sample which is then processed by the equipment. This processing is usually accomplished by the presentation of the material into an access port or onto a surface; the remaining processing takes place internally. Output of the data and its accuracy then depends on the reaction of the sample with chemicals or contact with the electrodes. The source and stability of these chemicals and the sensitivity and stability of the electrodes are the primary distinguishing factors discussed in the following paragraphs in this section.

Wet versus Dry Chemistry

Most of the invasive equipment investigated were based on the traditional wet chemistry technology. For most tests, these units require mixing the biological sample with reagents and processing the mixture for analysis by chemical reaction. For measuring blood gases, these units use flow-injection electrode analysis.

The newer dry chemistry technology requires that the biological sample be placed on paper that has been treated with a chemical reagent; the parameter of interest is then measured optically or electronically.

Skills Required to Obtain the Sample

Measurement of blood gas levels normally requires a sample of arterial blood. Measurement of electrolytes (K and Na), HCT, GLU, PTT, and BUN uses either a sample of arterial or venous blood. AE technicians must have the skill to obtain these samples in the aeromedical environment. Detection of OCC uses a vomitus sample. Testing for CSF would most likely be performed in the AMCL environment on clear liquids draining from the patient. In these last two tests, therefore, no special skill is needed for sample acquisition. Table 7 lists the capabilities of the clinical laboratory devices for which information was obtained during this study.

Invasive Equipment Comparison

This invasive equipment was evaluated against the criteria described in Section 5. Based on these criteria, four candidates were selected for further analysis. Table 8 provides detailed information on these candidates. Note that the two Nova devices are virtually identical except for GLU, which is measured on the SP5 unit only.

TABLE 7. CURRENTLY AVAILABLE EQUIPMENT

Vendor/Model	Type Chemistry	PO_2 PCO_2	Electrolytes	HCT	GLU	BUN
ABBOT/Vision	W		K only		X	
AMES/Clinistat	D		K only		X	X
AMES/Glucometer M	D				X	
AVL/982/995	W	X	X			
BECTON D/QBC	W			X		
BCHM/ISE/1500	W		X		X	X
CIBA/288	W	X	X			
IL/BGE	W	X	X	X		
IL/PHOENI	W		X		X	
KODAK	D		X	X*	X	X
MALLINCKRODT	W	X	X	X		
MEDICA/EL	W		X			
Nova/SP1	W	X	X	X		
Nova/SP2	W	X	X	X		
Nova/SP5	W	X	X	X	X	X
SERADYN/QL	W		X			

W = Wet Chemistry
D = Dry Chemistry
* = Estimated value from Hemoglobin
K = Potassium only

TABLE 8. COMPARISON OF INVASIVE EQUIPMENT

Equipment Information	Nova/SP5 Nova/SP2	Mallinckrodt	Kodak DT60 Kodak DTE
Chemistry			
Type	W	W	D
Reagents	Single Pack	Single Cart	Multiple Slides
Measured Parameters	pH, PCO_2, PO_2, Ca, Cl, HCT, GLU (SP5 only)	pH, PCO_2, Na, K, Ca, K, Cl, HCT	GLU, BUN, Hb, Cl, PO_2, Na, Chol, Urea (Add DTE for K, Na, Cl)
Electronics			
Type	Microprocessor	Microprocessor	Microprocessor
Measuring Technology			
PCO_2, PO_2	Severinghaus/ Clark Elect.	Miniature Severinghaus/ Clark Elect.	----
Na, K	ISE	ISE	ISE
HCT	Impedence	Conductance	Opt. Fixed WL
GLU	Enzyme	----	----
Programming Options	User Friendly	User Friendly	User Friendly

TABLE 8. COMPARISON OF INVASIVE EQUIPMENT (continued)

Equipment Information	Nova/SP5 Nova/SP2	Mallinckrodt	Kodak DT60 Kodak DTE
External Power	100/120V 200/220/240V	120V	110/240V
	50/60 Hz	50 Hz 100W	50/60 Hz
Internal Power	DC < 28V	DC < 28V	DC < 28V
Battery	Optional	Yes (30 Min)	Yes (20 Min)
Output			
CRT Display	Green Phosphor	LED	LCD
Printer	Ticket	Ticket	Ticket
Communication Interface	RS232/Modem	RS232	RS232/Optional
Samples			
Type	Whole Blood Serum,Plasma	Whole Blood	Plasma Serum
Volume	250 Syringes	500 Syringes	10/Slide
Container	Capillary Tubes Vacuum Tubes		Recharg. Pip.
Method of Input	Direct	Direct	Pipette
Analysis Rate	38	TBD	65 (DT60) 15 (DTE)
Test Time	95	109	390
Sample Acquisition Time	TBD	TBD	TBD
Operational Environment			
Vibrations	TBD	TBD	TBD
EMI/EMS	TBD	TBD	TBD
Power Variation	±10%	-15%, +10%	-10%, +5%
Temperature Range	61-86°F	TBD	60-85°F
Pressure Range	450-800 mmHg	TBD	TBD
Relative Humidity	Non-Condens	TBD	TBD
Illumination	Good	Good	Poor
Noise	TBD	TBD	TBD
Required Related Components			
Refrigerator	No	No	Yes
Freezer	GLU Caps Only	No	No
Gas Bottles	Yes	No	N/A
Waste Containers	Internal	Cartridge	Internal
Centrifuge	Yes/No	No	Yes
Pipettes	No	No	Yes
Price			
Equipment	$31,777(GSA) (SP5) $23,521 (SP2)	$21,000	$5,200 (DT60) $3,075(DTE)
Per Test	$0.46/sample	$6.50/sample	$1.60/slide

TABLE 8. COMPARISON OF INVASIVE EQUIPMENT (continued)

Equipment Information	Nova/SP5 Nova/SP2	Mallinckrodt	Kodak DT60 Kodak DTE
Physical Aspects			
Modular	Yes	No	No
Dimensions (DxWxH)(in.)	23x22x19	9x18x9	(DT60) 19x13x7 (DTE) 6x14x7
Weight (pounds)	100	27	34 (Both)
Patient-Side Convenience	No	Yes	Yes
Calibration and Accuracy			
Method and Frequency	Auto 2-Point 2-6 Hours Single Point W/Samples Manual	Auto 2-Point Hourly Single Point W/Samples Software	Auto Startup Every 6 Months Software
Startup and Cal.Time	7.5 Minutes	52 Minutes	60 Minutes
Recalibration Time	7.5 Minutes	5 Minutes	60 Minutes
Accuracy	± 3%	TBD	TBD
Correlation Coefficient	0.94-0.99	0.85-0.92	0.96-0.99
Maintenance			
Sensors	Monthly	72 Hours	Monthly (DTE)
Tubing	Annually	Daily	N/A
Reagents	18 Months	4 Months	12 Months
Skills			
Training	1 Hour	20 Minutes	30 Minutes
Operation	Easy	Easy	Easy
Maintenance	Moderate	Easy	Easy

Chol = Cholesterol
Hb = Hemoglobin
ISE = Ion Selective Electrode
LED = Light Emitting Diode
Noncondens. = Noncondensing
Opt. Fixed WL = Optical Fixed Wavelength
Recharg. Pip. = Rechargeable Pipette

Discussions with USAF and other military clinical laboratory personnel experienced in using the equipment listed in Table 8 provided the following information. Further information from these interviews appears in Appendix A. This information was used in evaluating the equipment for possible inclusion in an AMCL.

a) Kodak units use dry chemistry technology that reduces the workload associated with changing reagents and tubing in wet chemistry based devices. In addition, reagents for the latter technology can be affected by environmental factors and require greater storage space. In contrast, the dry chemistry tests have longer processing times.

b) Dry chemistry systems process serum samples; therefore, a centrifuge is needed to separate the whole blood. Several types of centrifuges are in use in USAF clinical laboratories. Units with floating heads may be most appropriate for use in aeromedical environments.

c) The dry chemistry approach may be expanded in the future to include the measurement of blood gases which significantly enhances this approach, if successful.

d) Clinical laboratory equipment can be affected by emissions from nearby radar sites. In addition, minor fluctuations in power lines can influence equipment output. Therefore, use of uninterruptable power supplies (UPS) is a must for clinical laboratory equipment.

e) Recent advances include the use of disposable cartridges for reagents as used in the Mallinckrodt equipment.

Vendors provided information by teleconference; five devices were demonstrated to the UTSA team during this study. This information is included in Appendix A. Excerpts of the data obtained on the devices described in Table 8 are as follows:

a) A Kodak Model DT60 is in use on U.S. Navy vessels and is undergoing testing by National Aeronautics and Space Administration (NASA). The Kodak units use a dry chemistry approach and, therefore, require a centrifuge to separate the serum from whole blood. The Kodak DTE module can be added to enable additional diagnostic tests. These units require monthly maintenance. Recalibrations may be needed only every 6 months. Given the need for slides (on which the sample is placed), the tests are more expensive than those performed using wet chemistry. Both units are lightweight and can readily be moved about between tests. Processing times for samples are significantly longer than for the wet chemistry devices. Data output for these units is via LCD requiring adequate environmental lighting. This can be a significant limitation for the current units if they are used under conditions prevailing in many aeromedical environments. In summary, the Kodak units have several distinct advantages including weight and the dry chemistry approach. However, the current units are not capable of measuring blood gases and, despite the low initial cost, per test costs are significant.

b) The Nova Statoprofile 5 performs most of the proposed diagnostic tests. It is large and heavy; however, an optional configuration includes a cart that contains the device and two gas cylinders (pressurized to 2000 psi). This cart weighs 85 pounds and also contains a UPS with an optional battery. Reagents are provided in a single pack that is easy to replace, as is the tubing. Replacement of the electrodes is required monthly and requires moderate training. Recalibration and adjustments for changes in barometric pressure are accomplished automatically. The Nova is easy to operate and provides results relatively rapidly. Finally, the initial purchase price is high, but the per unit test costs are the least of all the units examined.

c) Information on the Mallinckrodt device (GEM-STAT) was obtained by several teleconferences. This device has a single cartridge that contains all replacement items and solutions, as well as a waste bag. These cartridges are useful for up to 50 samples. Start-up time with calibration is over 50 minutes. Recalibration is accomplished automatically every 5 minutes and it corrects for changes in temperature. It is lightweight and could be readily moved between tests operating on an internal battery back-up power supply. An additional advantage of this unit is that gas cylinders are not required even though it can measure blood gases. A major aerospace firm, McDonnell Douglas, is evaluating this device for possible use on the space shuttle. In summary, its small size and weight, its capability for processing most of the diagnostic tests, and its lack of gas cylinders make this unit an

excellent candidate for use in an aeromedical environment. However, it has the highest per unit test costs for any of the units examined.

NONINVASIVE EQUIPMENT

To avoid the necessity of drawing arterial blood samples, noninvasive techniques were investigated. Two techniques are currently available for noninvasive measurement of blood gases, transcutaneous measurement and oximetry. Transcutaneous measurements use electrodes for the detection of gases that diffuse through the skin. Oximetry, in contrast, is based on optical measurements of the changes in cutaneous vasculature. Wiedemann and McCarthy provide a current and fairly complete description of these technologies. This article is the primary source of information for this section and unless otherwise specified, all quotes in this section are taken from this article.

Oximetry

The first oximeters used the ear as the site for detection of arterial blood oxygen levels. One of the best of the original ear oximeters, the Hewlett-Packard 47201A, required eight different frequencies of light to accurately distinguish the effects of the various light absorbers in the body. These absorbers included the four types of hemoglobin (Hb): oxygenated (HbO_2), reduced hemoglobin (RHb), carboxyhemoglobin (COHb), and methemoglobin (MetHb), as well as skin pigments. Since this device could not differentiate between arterial and venous blood, it required heating of the tissue proximal to the sensor to increase the volume of blood in the cutaneous vasculature. This device and others using a similar approach did not find extensive use outside of laboratories because of their size, weight, large earpiece, and delicate fiberoptic cable.

Subsequently, the technology was enhanced and led to the development of pulse oximetry, currently the method of choice for those using oximetric techniques. This approach is based on the principle that light transmission through the tissue can be measured when the arteries are maximally or minimally expanded. Differences in these transmission measurements would be due to the changes in arterial blood volume that occur with each pulse. The detector in the pulse oximeter is optimally responsive to the wavelength of the light absorbed by HbO_2. Differences due to variability in placement, skin pigmentation, and other absorbers are negated because these factors are relatively constant between pulses. Aoyagi et al. give detailed review of this technology. The three major advantages of this approach are: (1) no heating of the sensor area is required to "arterialize" the blood; (2) only two frequencies of light are required to calculate HbO_2 since blood is usually composed of only two major light absorbers, HbO_2, and RHb; and (3) no person-to-person calibration required.

A potential limitation of this approach relates to the quantities of light absorber present in the skin. Since pulse oximetry is based on the assumption that HbO_2 and RHb are the primary absorbers in arterial blood, their readings can be significantly inaccurate when this assumption is not true. These concerns are reflected in the comments of Wiedemann and McCarthy: "In patients with significant hypoxemia (saturations below 65 to 70 percent), oximetry is frequently found to be less reliable than at higher saturations....Limited data are available on the performance of pulse oximeter under conditions of abnormal hemodynamics or temperature, such as might be found in critically ill patients....Bright external light sources, including sunlight, fluorescent lights, surgical lamps, and infrared heating lamps are capable of interfering with pulse oximetry....Pulse oximetry has been shown to be extremely accurate under a very wide range of hemodynamic conditions."

A major advantage to this approach is cited by J. J. Brodsky: "The data is available immediately, hence there is no delay while waiting for the results of blood gas analysis before instituting appropriate steps to improve oxygenation."

Transcutaneous Measurement

The transcutaneous measurement of arterial oxygen levels is based on the observation that the partial pressure of oxygen in the skin ($PtcO_2$) heated to 45°C is approximately equal to the partial pressure of oxygen in arterial blood (PaO_2). Heating is required to increase the arterial blood volume in the cutaneous vasculature and to increase the rate of diffusion of the gases. This observation was made in 1951 by J. B. Baumberger and R. B. Goodfried. In 1972, a small heated Clark electrode placed at the skin surface was developed. The heating of the skin serves three purposes: (1) the oxygen hemoglobin dissociation curve is shifted to the right (therefore into the more linear region); (2) the structure of skin is altered allowing faster oxygen diffusion; and most important, (3) the blood flow through the skin is greater, thereby increasing the volume available for detection. These effects allow for close approximation of PaO_2 by oxygen tension ($PtcO_2$), which is the parameter measured by the Clark electrode. A disadvantage of this technique is the potential for skin burns from the heat source. Once a sensor is relocated, the system must be recalibrated; the total time for relocation and/or recalibration can take up to 30 minutes. Periodic recalibration is required every 4 to 6 hours even if the sensor site has not been changed. After initial placement of the sensor at a site, it may take 5 to 10 minutes for the $PtcO_2$ to stabilize. After stabilization, the response time for detecting physiologic changes range from 60-180 seconds.

Transcutaneous measurement of the partial pressure of carbon dioxide in arterial blood ($PaCO_2$) can also be accomplished. An infrared sensor or a pH electrode can detect the level of $PtcCO_2$.

A potential limitation for the transcutaneous measurement of carbon dioxide was cited by Wiedemann and McCarthy: "Decreases in cardiac output and tissue perfusion significantly affect the $PtcCO_2$ - $PaCO_2$ gradient, analogous to the situation with transcutaneous oxygen monitoring. At a cardiac index of less than 1.5 liters per minute per square meter of body surface area, $PtcCO_2$ rises markedly above the corresponding $PaCO_2$ value and no longer tracks changes in $PaCO_2$."

Comparison of Pulse Oximetry and Transcutaneous Measurement

Review of the technical journals, vendors' literature, and discussions with several technical representatives permitted the development of an inventory of available pulse oximeters (Table 9) and transcutaneous oxygen and carbon dioxide monitors (Table 10).

TABLE 9. PULSE OXIMETER

Vendor	Model
Baxter Health Care Corporation	ASAT
BioChem International	1040A, 3100, 3040, 7700
Criticare Systems, Inc.	CSI 501
John Bunn Co.	OXI-Pulse
Healthdyne	Model 930
Kontron Instruments	7840, 7845
Marquest	PULSOX-7
Nellcor	N-10, N-100, N-200, N-1000
Nonin	8500, 8604DL, 8604DLM, 8700, 8800
Ohmeda	BIOX 3700
Pace Tech	Oximax 100, Oximax 700, Oximax 700, Vitalmax 2000
Physio Control	LIFESTAT 1600
Radiometer	OXI-1, OXI-2, OXI-3, OXI-3H, OXI-4, OXI-4H
SpaceLabs	90419

TABLE 10. TRANSCUTANEOUS MONITORS

Vendor	Model	$PtcO_2$	$PtcCO_2$
Air-Shields	AS301		
BioChem International	MicroSpan Combo	X	X
Kontron Instruments	Microgas 7640	X	X
Novametrix	840	X	X

Review of the available literature on these pulse oximeters indicated that the similarity of their features did not warrant a separate discussion of any individual differences. A similar statement holds for all transcutaneous oxygen and carbon dioxide monitors. Comparison between the two technologies, however, revealed several significant differences beyond just the sensor technology. Table 11 summarizes the essential characteristics for these two noninvasive approaches to measuring arterial oxygen. With the transcutaneous approach it is also possible to assess arterial carbon dioxide levels.

TABLE 11. COMPARISON OF NONINVASIVE TECHNOLOGIES

Categories	Transcutaneous	Oximetry
Measured Parameters	$PtcO_2$ $PtcCO_2$	SaO_2 Pulse
Sensor Sites	Varied	Forehead Ear Finger
Electronics		
Type	Digital	Digital
Measuring Technology	Heated Electrode	Optical
Programming Options	Alarms	Alarms
External Power	110/220V, 50/60 Hz	110/220 V, 50/60 Hz
Internal Power	Direct Current	Direct Current
Battery	Usually	Usually
Output		
Digital	Yes	Yes
Analog	Yes	Yes
Printer	Yes	Yes
Communication Interface	Yes	Yes
Response Time	10-20 Seconds	5 Seconds
Physical Aspects		
Dimensions (max), inches	8 x 16 x 14	9 x 11 x 1
Weight, lbs.	3.5-20	1-10
Patient-Side Convenience	Yes	Yes

TABLE 11. COMPARISON OF NONINVASIVE TECHNOLOGIES (continued)

Categories	Transcutaneous	Oximetry
Calibration and Accuracy		
Method and Frequency	2 point, Electronic	None Needed
Start-up Cal.	30-40 Minutes	None Needed
Recalibration Time	Every 4-6 Hours	None Needed
Accuracy	4 Percent	3 Percent
Maintenance		
Sensors	Change Membranes Every 7 Days	Very Little
Skills		
Training	Minimal	Minimal
Operation	Precise	Minimal
Maintenance	Precise	Minimal
Operational Environment		
Vibrations	TBD	TBD
EMI/EMS	TBD	TBD
Power Variation	30 Percent	30 Percent
Temperature Range	5-40°C	10-45°C
Pressure Variation	0-10,000 Feet	TBD
Relative Humidity	10-90 Percent	10-90 Percent
Noise	TBD	TBD
Related Components		
Gas Bottles	Yes	No
Calibration System	Yes	No
Price		
Equipment	$3,000 to $12,000	$2,500 to $10,000
Calibration System	$5,000	None Needed

SaO_2 = Percent Hemoglobin Saturated with Oxygen
$PtcO_2$ = Transcutaneous Partial Pressure of Oxygen
$PtcCO_2$ = Transcutaneous Partial Pressure of Carbon Dioxide

SYSTEMS REQUIREMENTS FOR AMCL EQUIPMENT

The conclusion drawn from analyses of the equipment examined during this project is that the technology is available for development of an AMCL. It is also apparent that virtually none of the current devices has been subjected to reliability testing--the ability to withstand the extremes of temperature, vibration and other limiting operational factors. If an interim system is required, it is recommended that a preliminary design specification be developed as a baseline for lead-off analysis and evaluation of candidate systems and technologies.

It is also recommended that the USAF examine the potential for developing an AMCL that incorporates the best components and technology of the available units which may prove to be an effective mid-term solution. For the long term, it is recommended that the USAF examine the use of noninvasive technologies to accomplish more of the tests. The many advantages of this

approach include continuous monitoring of individual patients and reduced workload for the aeromedical personnel in drawing and processing blood samples, etc. The following sections provide recommendations for short-term and long-term solutions based on the clinical laboratory equipment examined during this project.

Short-Term Solutions

It is feasible to use off-the-shelf equipment that is "hardened" to make up for design shortcomings in the currently available equipment. Based on information available at this time, the following corrective measures will be needed: battery power, vibration suppression, heaters/chillers for the temperature control of reagents, and electromagnetic shielding. Additional measures may be required depending on the results of developing a specification for equipment compatible with the aeromedical environment.

Given the technology available today, and the proposed diagnostic tests, it is recommended that equipment requiring an invasive approach be considered as a short-term solution. Since the invasive approach requires drawing arterial blood samples, this equipment will be most useful in those settings with a relatively stable platform and adequate lighting. Among the devices described herein, several are capable of performing virtually all of the blood-related diagnostic tests. Preference at this time for units that use wet chemistry is obvious because the dry chemistry approach does not test for blood gases. Given the data available, the equipment produced by both Nova Biomedical and Mallinckrodt provide the best capabilities. Only Nova offers a unit (SP5) that can test for all of the blood-related parameters except BUN and OCC. This unit is far more expensive than the others. By removing the GLU requirements, both the SP2 of Nova and the Mallinckrodt units are suitable selections. Cost reduction will be a major concern in any selection process. Data on GLU can now be obtained from chemstrips or by one of the inexpensive devices dedicated to GLU measurements only. The chemstrip approach should also be the method of choice for determination of OCC.

Measurement of PTT requires the use of a dedicated device. Information was obtained on devices available from Medical Laboratory Automation, Inc. (MLA 700 Series), Baxter Biomedical (Fibrometer), General Diagnostics, and Abbott Laboratories. Selection from among these or other vendors must await further data analysis. Any device selected for this purpose can then be integrated with the other equipment into an array for use in the aeromedical environment.

A combination of invasive and noninvasive equipment should also be considered, especially when crew workloads will not permit time for routinely processing blood samples from a number of unstable patients. For the short-term, any of the invasive units described in this section, as well as the Kodak unit, are suitable for obtaining most of the blood-related data (with the exception of blood gases). Information on blood gases can be obtained by using either the pulse oximeter or transcutaneous devices. In reviewing the information provided, it is recommended that pulse oximetry is a more suitable approach for use in the aeromedical environment if a proper accuracy range can be consistently achieved. This recommendation is based on the flexibility in locating the sensors, lack of requirements for both heating of the skin, and on-site calibration. Choosing among the various oximetry devices is possible at this time because the Biochem 1040A has recently been approved for aeromedical use by the Aeromedical Equipment Evaluation Laboratory at Brooks AFB, TX.

Should there also be a requirement for monitoring PCO_2, a transcutaneous approach is required at this time. One of these transcutaneous devices could be used exclusively for the PCO_2 or could replace the oximetry device and be used to monitor both PCO_2 and PO_2. The latter alternative is not a simple one since PO_2 detection requires higher skin temperatures than PCO_2 detection. Since PCO_2 can be measured at lower temperatures, there is less need to relocate the sensor and less chance of skin injury, but the response time is longer.

In summary, the array of equipment shown in Table 12 is recommended. Note that, in some cases, a specific unit is not listed and must await further evaluation as described previously. The requirement for the invasive device to measure blood gases should remain, especially where the setting permits drawing of arterial blood samples. Even with the noninvasive devices providing the capability to monitor PO_2 (and even PCO_2), there may be a need to periodically obtain an arterial sample to provide an overall assessment of the blood gases and pH. The arterial sample is even more essential if only the PO_2 monitor is used. Finally, note that BUN cannot be obtained at this time from the recommended array of equipment. Based on input from the aeromedical consultants, this shortcoming is not sufficient to eliminate the devices described.

TABLE 12. RECOMMENDATIONS FOR AN AMCL

Diagnostic Test	Recommended Approach
Arterial Blood Gases:	
PO_2	Invasive: Nova SP2 Noninvasive: Biochem 1040A
PCO_2	Invasive: Nova SP2 Noninvasive: Transcutaneous
pH	Invasive: Nova SP2
Plasma Electrolytes: K Na	Nova SP2
Hematocrit	Nova SP2
Blood Glucose	Chemstrips
Occult Blood	Chemstrips
Cerebrospinal Fluid	Observation/Chemstrips

Long-Term Solution

There are some advantages for a dry chemistry approach for the invasive equipment. Among these advantages are that the devices: (1) require less maintenance (no internal fluid tubing and reagents); (2) require less frequent recalibration; and (3) increase mobility. Among the equipment described in Table 8, the Kodak units are recommended for further analysis. A distinct advantage of these units is that BUN can also be tested. At this time, use of the Kodak unit will require the use of noninvasive PO_2 monitors. Although only speculation at this time, the dry chemistry approach may be expanded to include detection of blood gases. While an arterial blood sample will still be required, reduced maintenance for these units could make dry chemistry an attractive alternative long-term solution.

There is always the possibility that novel approaches to these diagnostic tests may be developed in the future. Review of the technical journals and patent literature at this time does not suggest any truly revolutionary approaches in the next few years. Therefore, the recommendations made in this report can serve as the foundation for a decision to proceed on developing and fielding a clinical laboratory system for aeromedical operations.

APPENDIX A

SUMMARY OF VISITS, DEMONSTRATIONS, AND TELECONFERENCES

Summary of Visits:

1. Brooks AFB Main Clinic (11/16/89)
2. Wilford Hall - Main Laboratory (11/16/89)
3. Brooks AFB - USAFSAM/NG (11/30/89)
4. Academy of Health Sciences, Ft. Sam Houston, Lt. Cmdr. J. White (12/19/89)

Summary of Demonstrations:

1. Abbott Laboratories Diagnostic Division (11/21/89)
2. Instrumentation Laboratory (10/31/89)
3. Eastman Kodak (11/20/89)
4. Nova Biomedical (11/30/89)
5. Seradyn Diagnostics (11/17/89)

Summary of Teleconferences:

1. Beckman Instruments (10/89)
2. BioChem Laboratory Systems, Inc. (12/89)
3. CIBA Corning (10/89)
4. Mallinckrodt Sensor Systems (1/15/90 and 5/1/90)
5. Medica (10/89)
6. Miles Diagnostic Division, Ames Inc. (11/17/89 and 11/20/89)
7. Nova Biomedical (10/24/89)
8. Statspin Technologies (unknown)

SUMMARY OF VISIT TO BROOKS AFB CLINIC

DATE: 16 November 1989, 9:00 A.M.

Contact Person: Sgt. Winget

Size of Clinic: Small

a. General Information (Capabilities):

- Class D laboratory.
- Emergency and some routine work.
- Minimal lab testing.
- All of the chemistry work is sent out.
- Refrigerator is used for blood and reagents storage.
- Sgt. Winget prefers modular to multiunit devices.
- Never checked vibration level - never had problems.
- No interference problems.

b. Equipment:

1. Cell counter.
   - Complete blood count.
   - In-house maintenance.
   - 1.5 years old.
   - No major problems.
   - For major problems calls manufacturer.
   - Once a year tubing replacement.
   - Display on the unit shows time for changing reagents.
   - Reagents require refrigeration.
   - No major problems with unit so far.
   - Equipment easily moved.
   - Easy to learn and operate.
   - Operating procedure is displayed.
   - Equipped with a printer.
   - Self testing mode.
   - Once every 3 months calibration.
   - Power is on 24 hours a day.
   - Waste bottle is outside the unit.
   - No training needed.

2. Urine Analysis.
   - Uses two microscopes.

3. Centrifuges.
   - 2 small/1 large.
   - Small unit is more practical.
   - Centrifuges have been troublefree.

4. Glucometer (Ames).
   - Uses dry chemistry.
   - Excellent device.
   - Small size.

- Easy to use.
- Only problem is for high limit (not high enough for diabetes).
- No training needed.

5. Kodak Ektachem for glucose and BUN.
   - Unit is on loan.
   - Dry chemistry.
   - Reagents are in a small slide.
   - Slides are bar coded.
   - Machine reads bar codes.
   - Fully automatic.
   - Instructions are very easy to follow.
   - Very accurate; glucose was tested against the results from Wilford Hall.
   - No training needed.
   - Has not been used much to determine reliability.
   - Interference, vibration, movements unknown.

SUMMARY OF VISIT TO MAIN LABORATORY AT WHMC

Date: 16 November 1989, 1:00 p.m.

Contact Person: Col. H. T. Cerha

Size of Clinic: Large (750,000 tests/month)

a. General Information:

- Almost all equipment is bench type for large number of tests.
- Major Problems: Radar tower very close to the computers. Minor fluctuations in the power lines influences the results on equipment. Temperature variations affect reagent's stability. Equipment is very sensitive to room temperature variations.
- Repair and Maintenance: In-house maintenance in addition to service contracts. Newer models are easier to maintain and repair. Blood gas analyzers are the most sensitive devices and have maintenance program.
- Most of the units are easy to operate.
- For complex equipment, training seminars are conducted.
- No preference on single function or multifunction units.
- Dry chemistry requires less storage space as opposed to wet chemistry.
- Dry chemistry more expensive than wet chemistry.
- Dry chemistry requires more time for testing.
- Dry chemistry uses serum; therefore, centrifuge is needed.
- Use of centrifuge on aircraft may be a problem.
- Not all the equipment has internal waste container.
- Have problems with Instrumentation Laboratory equipment.

b. Equipment:

(1) Hematology Laboratory

- Large laboratory.
- Bar code driver diagnostic test using multiple samples.
- Urinalysis machine equipped with microscope.
- Refrigerated centrifuge.
- Automated analyzer with bar code (no blood gases).
- Synchron Clinical System Analyzer measures glucose and electrolyte, manufactured by Beckman.
- ACA III Analyzer by Dupont (no blood gas).
- Diluents, using serum.
- Almost all the equipment in hematology lab uses serum samples.

(2) Blood Gas Laboratory

- Small laboratory.
- Kodak Ektachem 700 XR Analyzer, large size, uses serum samples, no blood gas.
- Three-piece bench type, small size, blood gas-electrolyte analyzer, by ABL, note single gas cylinders.
- UPS by powermaker. UPS is a must for analyzers.
- Blood gas analyzer with co-oximeter and printer made by IL, large to medium size gas cylinders with up to 2000 psi pressure, uses whole blood (all blood gas analyzers use whole blood), many problems with this unit.
- Electrolyte analyzer by Nova Biomedical.

- Holders for gas cylinders for ABL.
- Packaged gas cylinders.

c. Comments:

- Large equipment.
- Large number of tests.
- Most of the electrolyte analyzers in hematology lab are bar coded and automated.
- Calibration usually once a day except for units such as IL which has self calibration function every 4 hours.
- Maintenance, cleaning, changing/inspecting reagents, changing tubing performed every night for 1 hour.
- 24-hour/day testing.
- Maintenance and inspection performed by medical technicians.
- Twenty minutes maximum is the time for blood on ice from patient to analyzer.
- Nova STATPROFILE 5 will be added to Blood Gas Lab in near future.
- UPS is a must for a laboratory.
- Maintenance and calibration of blood gas analyzers very important.
- Had problems with EMI in the past.
- No experience with vibration.

SUMMARY OF VISIT TO USAFSAM/NG LABORATORY

Date: 30 November 1989, 1:30 p.m.

Contact Person: Sgt. Anderson

Size of Laboratory: Small

Attendees: J. Eftekhar and P. Olivier

a. General Information:

- Small laboratory.
- Power fluctuations.
- Suggest using dedicated power lines with surge protectors.
- Problems with blood coagulation.
- Fiber clotting is the major problem in testing.
- Machines are not capable of distinguishing bad from good reagents.
- Use of precoated syringes with anticoagulants is highly recommended.
- An electromagnetic shield is suggested for protection against EMI.
- A vibration-proof table for use in aircraft is available.
- All units are easy to operate and maintain.

b. Equipment:

- Beckman Model TJ-6 Centrifuge. This centrifuge is equipped with a head with more freedom of movement.
- CIBA Corning 664 Fast 4 System. Self-contained waste. Whole blood and serum. Easy to change electrodes. Reagents kept at room temperature.
- CIBA Corning 550 Express. Measures Glucose, BUN, CK, CKMB. Does not test for electrolytes. Easy to operate and maintain.
- Refrigerators and freezers.

SUMMARY OF VISIT TO U.S. ARMY ACADEMY OF HEALTH SCIENCES

Date: 19 December 1989, 8:25 a.m.

Location: Academy of Health Sciences
Laboratory Science Division
Ft. Sam Houston

Contact Person: Lt. Cmdr. Joe White
DEPMEDS Laboratory Panel Member
(512) 221-4859

Attendees: J. Eftekhar, T. Kingery

a. General Information:

Q. What are the criteria for selection of the equipment for clinical laboratory?

A. No specific criteria; We look at our requirements such as frequency (60/50 Hz) and then check the equipment if it satisfies the requirement.

Q. Do you have a list of companies that sell diagnostic test equipment?

A. No list; however, I have a collection of catalogs.

Q. What are the new technologies that are available in the market?

A. Gem Systems by Mallinckrodt Sensor Systems is an example of new technology using disposable cartridges.

Q. What are the technologies that will be available in the near future?

A. Dry chemistry. Kodak which uses dry chemistry is working on blood gas analyzer which is in the development stages.

Q. What kind of diagnostic tests do you think is required for the AMCL?

A. Hematocrit, blood gases (maybe), HbO_2 Sat. (maybe). Do not recommend electrolyte, glucose, BUN, and PTT.

Q. Have you addressed maintenance and inspection issues for the equipment that has been evaluated?

A. No.

Q. Do you know of any clinical lab equipment that has been tested for: susceptibility to electromagnetic radiation, susceptibility to any kind of interference, ability to operate in a vibrating environment, and ability to operate under fluctuating power?

A. No.

Q. Has any work been done to "harden" the equipment for these issues, e.g., use of shields?

A. No.

Q. Do you have a list of clinical equipment that has been approved by NASA?

A. No. However, Dr. Robert Mosebar of the AHS Combat Development office has worked with NASA on this issue.

Q. Do you have a list of clinical diagnostic equipment that has been approved to be used on a ship?

A. Not really, only chemistry analyzer, hematology, venereal diseases, and pregnancy tests.

Q. Do you have a list of clinical diagnostic equipment that has been approved to be used on ground vehicles?

A. Light infantry is the only one.

Q. What is your preference "dry" or "wet chemistry" and why?

A. No preference.

Q. Use of serum vs. whole blood?

A. Prefer serum; however, centrifuge needed.

Q. Have you considered human factors, e.g., weight, dimensions, location, lighting in the selection of the equipment?

A. Only weight and volume.

Q. Any preference in method of sampling?

A. Direct sampling, no pipet.

Q. Any preference in method of testing?

A. No.

Q. Do you know of any portable automated monitoring system?

A. No.

Q. Have you evaluated any equipment for their calibration, accuracy, speed of testing and analysis?

A. Some older models.

Q. Have you evaluated any floating head centrifuge?

A. Yes, STATSPIN, which is a very good device.

b. Other Comments:

- No blood gas analyzer in the market which is field worthy.
- Mallinckrodt Gem Systems may be good for field tests.

- Gem-Stat blood gas analyzers do not require gas cylinders.
- Gem-Stat is a good analyzer; however, accuracy of the tests is not good.
- Reagent packs don't need refrigeration.
- Gem-Stat needs to be tested for aircraft.
- Gem-6 was evaluated and presented problems at high temperatures.
- Gem-Stat needs little maintenance.
- Each cartridge cost $350.00.
- Gem-Stat will not do chloride.
- Haven't checked any oximeters.
- Blood gas analyzer is needed first before using oximeters.
- Gilford Industries equipment has shown problems with reagents, and large space is needed for storage.
- Do not recommend electrolyte (maybe), BUN, glucose, PTT tests aboard the aircraft.
- Kodak is a good dry chemistry unit; however, problems with refrigeration.
- Kodak at this time doesn't have blood gas analyzer, but one is in the development stage.
- Kodak pipets are good and accurate.
- Stat Spin III is a very good centrifuge for aircraft use.
- Prefer one unit vs. a multiunit for diagnostic tests.
- No automated monitoring.
- Do not recommend electrolyte, since it will not change significantly in the first 10-12 hrs.
- Hematocrit decreases rapidly, especially for someone who is bleeding.
- Blood gases change rapidly.
- PTT is usually for post-operation phase.
- HbO_2 Sat. (calculated) will be useful.

c. Deployable Medical Systems (DEPMEDS):

Following is information furnished by Lt. Cmdr. J. White on clinical laboratory procedures as found in DEPMEDS. He indicated that the figures shown are for technician time and do not include machine time.

DEPMEDS LABORATORY PROCEDURES (TASKS)

Procedures performed at NATO Echelons 3 and 4 are as follows:

CHEMISTRY

Task No.	Description	Ech 3	Ech 4	Time
E001	Perform blood gas estimation	X	X	6.0
E002	Determine electrolyte levels (Na, K, Cl, CO_2)	X	X	27.0
E003	Determine total serum protein level	X	X	6.0
E004	Determine urine protein level	X	X	6.0
E005	Determine serum creatinine level	X	X	13.0
E007	Determine serum analyze level	X	X	13.0
E008	Determine SGPT level	X	X	9.0
E009	Determine creatine phosphokinase (CPK) level	X	X	9.0
E010	Determine blood glucose level	X	X	10.0
E011	Determine BUN level	X	X	9.0
E012	Determine serum bilirubin	X	X	9.0
E013	Determine spinal fluid sugar level	X	X	10.0
E014	Determine spinal fluid protein level	X	X	10.0
E017	Determine calcium level	X	X	9.0
E015	Determine SGOT level		X	9.0

HEMATOLOGY/URINALYSIS

Task No.	Description	Ech 3	Ech 4	Time
E020	Perform complete blood count	X	X	18.0
E021	Perform white cell count	X	X	6.0
E022	Determine hematocrit level	X	X	3.0
E024	Perform white cell differential count	X	X	11.0
E025	Perform prothrombin time (PT)	X	X	8.0
E026	Perform PTT	X	X	10.0
E028	Perform spinal fluid cell count and differential	X	X	18.0
E029	Perform urinalysis w/specific gravity	X	X	6.0
E030	Perform microscopic urinalysis	X	X	4.0
E031	Perform platelet estimate	X	X	2.0
E032	Perform platelet count	X	X	9.0
E033	Perform fibrinogen level and fibrin split products		X	14.0

MICROBIOLOGY/SEROLOGY

Task No.	Description	Ech 3	Ech 4	Time
E027	Perform occult blood determination	X	X	4.0
E043	Perform Gram stain	X	X	6.0
E044	Perform rapid plasme reagin (RPR) test for syphilis	X	X	3.0
E045	Perform mononucleosis spot test	X	X	5.0
E046	Perform thick and thin smear for malaria	X	X	22.0
E047	Examine feces for ova, cysts and parasites	X	X	33.0
E048	Perform potassium hydroxide (KOH) preparation	X	X	8.0
E049	Perform pregnancy determination	X	X	5.0
E019	Identify anaerobes		X	10.0
E035	Perform urine culture (colony count and susceptibility)		X	15.0
E036	Perform wound culture and susceptibility		X	26.0
E037	Perform blood culture and susceptibility		X	18.0
E038	Perform sputum culture and susceptibility		X	23.0
E039	Perform stool culture and susceptibility		X	23.0
E040	Perform spinal fluid culture and susceptibility		X	23.0
E041	Perform throat culture		X	11.0
E042	Perform culture and susceptibility for gonorrhea		X	17.0
E051	Perform microscopic exam for acid fast bacteria		X	14.0

BLOOD BANK

Task No.	Description	Ech 3	Ech 4	Time
E052	Perform blood T&C (ABO, Rh) (3 units)	X	X	38.0
E057	Perform thaw and wash of frozen RBCs (2 units)	X	X	45.0
E058	Perform thaw and wash of frozen platelets (6 units)	X	X	40.0
E059	Perform thaw of fresh frozen plasma	X	X	10.0

ANATOMIC PATHOLOGY/CYTOLOGY

Task No.	Description	Ech 3	Ech 4	Time
E034	Perform bone marrow specimen analysis		X	48.0
E053	Perform cytologic examination, Non-Gynecological (GYN)		X	NA
E054	Perform cytologic examination, GYN		X	NA
E055	Perform histologic/surgical examination		X	NA
E056	Perform autopsy		X	NA

SUMMARY OF DEMONSTRATIONS OF ABBOTT LABORATORIES EQUIPMENT

Date: 21 November 1989

Telephone: (800) 342-5228

Equipment: Vision

Diagnostic Tests: 2 (K only), 4

Type: Invasive

a. General Information:

- Major tests; Ca, cholesterol, glucose, hemoglobin, K, urea nitrogen.
- No blood gases.
- Serum, plasma or whole blood.
- Runs 1 to 10 tests simultaneously.
- Internal centrifuge with 1800 rpm platter speed.
- Sample volume 50 µl.
- No electrodes, optical (polychromatic).
- Uses extraction technology.
- Troubleshooting program with maximum 48-hour replacement time.
- Very easy to use.
- Ready to use test packs which eliminate the need for reagent reconstitution.
- Takes approximately 8 minutes for results.
- Finger stick or venipuncture specimens.
- Ticket printer.
- Wet chemistry.
- Uses capillary tube or pipet.
- Internal beeper.
- Light source: pulsed xenon arc.
- Principles of operation: Diluent, reagent, and specimen fluids are inside the pack. During centrifugation, acceleration causes reagent and diluent to flow into reagent measuring chamber. At the same time, blood plasma is separated from cells. Specimen volume is then measured and mixed with reagents during second rotation cycle. Absorbencies are measured, reaction is incubated, and results are calculated and printed.
- Optical with wavelength range of 340-633 nm.

b. Power:

- 110/120/220/240 VAC.
- Accepts 10% voltage variation.
- 60/50 Hz, 10 amps.
- Maximum 850 watts.

c. Calibration: Yes.

d. Vibration Tests: None, very sensitive unit, requires flat, leveled surface.

e. Interference Tests: Manufacturer recommends that the unit be kept away from electrical appliances which use "liquids electric motors."

f. Dimensions: 23" W x 17" H x 23" D.

g. Weight: 70 lbs.

h. Display: LED.

i. Environmental Requirements: Room temperature 15-30°C adequate ventilation with 6-inch clearance.

j. Comments: Very sensitive device, good technology with use of internal centrifuge. Portable, internal heater, new tests will be added in future, easy to operate.

SUMMARY OF DEMONSTRATION BY INSTRUMENTATION LABORATORY

DATE: 31 October 1989, 8:00 A.M.

Demonstration by: Don Boyd, Chemistry Specialist and Medical Technician
(800) 552-2025, Ext. 6117

Attendees: J. Eftekhar, A. Bast

Equipment: BGE Lectrolytes Model 1400

Diagnostic Tests: 1, 2, 3

Type: Invasive

a. General Information:

- Blood gas, electrolytes, and hematocrit from a single sample.
- Nine-inch screen and ticket printer.
- Two floppy disks and a data management system.
- One disk is used to store data for patients and one for system.
- Sample size 240 µl.
- Measured parameters: pH, PO_2, PCO_2, Na+, K+, Ca++ and Hct.
- Calculated parameters: HCO_3, SBC, TCO_2, Base Excess - blood, Base Excess - extracellular fluid, percent SO_2, Ca (at pH 7.4), Hb, plus A-a difference in O_2 and RI.
- Can be interfaced with IL482 co-oximeter.
- Requires instructions.
- Requires training for maintenance.
- Government Price 21.8K.
- Power (internal) 5-12 VDC.
- Approximately 1 minute for all tests.
- Works good from ground level up to 10,000 feet elevation.
- One parallel port.
- Four serial ports.
- Maintenance program with reminder.
- Power fail program.
- Electrode technology.
- Reagents can be stored at room temperature for 30 days.
- Easy to replace electrodes.
- No need for centrifuge.
- Tubing must be replaced monthly.
- Self-contained waste.
- May use blood for oximetry instead of noninvasive technique.

b. Power:

- Seven different voltages ranging from 5 to 12 VDC.
- Six transformers.
- May use 110 VAC, 5 amp invertor to use aircraft 28 VDC.

c. Calibration:

- Continuous (mathematical correction).
- Automatic.

- Set point.
  - pH calibration between 6.84 and 7.384.
  - Continuous calibration - 5 times/second.
  - Barometric pressure manually or automatically monitored.

d. Vibration Tests:

- None; however, it has been used on ground vehicles.

e. Interference Tests: None

f. Dimensions: 23.5 x 17.3 x 20.1 inches without oximeter.

g. Weight: 101 pounds.

h. Display: N/A

i. Other Products:

(1) IL co-oximeter measures total hemoglobin, oxyhemoglobin, carboxyhemoglobin, methemoglobin, and reduced hemoglobin. Carboxyhemoglobin results useful for brain injuries. Ear oximeters only measure SO_2, using optical device; not accurate.

(2) Phoenix Electrolyte Analyzer. Uses Ion Select Technology (ISE). Measures: Na, K, Cl, TCO_2, Glucose, Urea, Nitrogen, Ca.

j. Comments:

IL BGE Lectrolytes performs all the diagnostic tests but requires two persons for transportation. Requires a nurse station (cannot be taken to the patient). May require an isolated chamber for vibrations and interference. Some laboratories (i.e., Wilford Hall) had problems with older model.

SUMMARY OF DEMONSTRATION BY EASTMAN KODAK

DATE: 20 November 1989

Demonstration by: John M. Jones
Diagnostic Sales Representative
(512) 342-2716 or (800) 521-0098

Equipment: EKTACHEM DT60 and DTE Module

Diagnostic Tests: 2, 4, calculates 3

Type: Invasive

a. General Information:

- Dry chemistry.
- Used on U.S. Navy vessels.
- Used on cargo and passenger ships.
- NASA is testing the unit.
- Easy to use.
- Uses small slides.
- Uses plasma and serum.
- For non-immediate testing, serum and plasma must be separated.
- Equipped with ticket printer.
- Finger stick or venipuncture draw.
- Sample Size: 10 µl per slide.
- Slides are layered dry.
- Slides with reagents.
- Twenty-five slides per box.
- Bar coded slides for test identification.
- DT60 and DTE module measure glucose, BUN/urea, cholesterol, hemoglobin, Na, K, Cl, CO_2, and other tests.
- Operational temperature rang 60° to 85°F.
- No blood gases.
- Requires a centrifuge.
- Kodak recommends STATSPIN centrifuge.
- Accuracy of results: 5 percent to reference method (according to sales representative).
- Correlation coefficient: 0.96 - 0.99.
- Does not measure hematocrit, but calculates it.
- Battery (rechargeable) operated pipet that releases sample automatically.
- Sample is ejected on the slide, even when the unit is upside down.
- Start up and calibration time: 1 hour.
- 1.5-minute testing time and 5-minute processing (3 minutes for electrolyte).
- 100 tests/hour for the system.
- Analysis Rate: 65 (DT60), 15 (DTE) samples/hour.
- Calibration every 6 months (using same lot number).
- No internal auto calibration.
- Recalibration time: 1 hour.
- Uses three slides per calibration (four for electrolyte).
- Easy maintenance.
- Slides are predated.
- Usually slides expire in 18 months.

- Requires refrigeration.
- Contains a slide disposal box.
- Does not work on comparison, uses calibration (for electrolyte, makes a comparison check).
- Requires three slides per calibration tests (four for electrolyte).
- Pipet sprays two fluids, one for reference and one for sample.
- Two modules can be connected to DT60.
- Very easy to operate with minimal instructions (30 minutes).
- No need for further instructions.
- A test was performed at UTSA with the unit tilted approximately 30 degrees. The pipet ejected the sample at the center of the slide.
- Uses optics for analyzing tests and ISE for electrolyte.
- Restart time after power loss depends on length of power loss and its effect on incubator temperature (2-20 minutes.)
- Average cost per test: $1.60.

b. Power: 110-240V - 10 percent + 5 percent, 50-60 Hz.

c. Calibration: Once every 6 months.

d. Vibration Tests: U.S. Navy and NASA use this equipment; however, no tests have been performed.

e. Interference Tests: None.

f. Dimensions: (DT60) 18.75 x 13.75 x 6.75 inches.
(DTE) 5.75 x 13.9 x 6.5 inches.

g. Weight: (DT60) 25.6 lbs, (DTE) 8.1 lbs.

h. Display: LCD (poor), requires artificial lighting.

i. Other Products: The following module may be connected to DT60: Ektachem DTSC Module, Ektachem DTE Module.

j. Comments:

- Lightweight, patient-side convenience.
- Easy to use.
- Easy calibration (once every 6 months).
- Accurate pipet.
- Sealed slides.
- No effect of humidity on slides.
- Internal DC power with 20-minute rechargeable battery.

k. Problems:

- No blood gas measurement.
- Long testing and processing time.
- LCD display.
- Needs refrigeration and sometimes freezing for slides.
- Requires a centrifuge.
- Calculates hematocrit.

- Accuracy may suffer since there is no direct comparison for most tests (except for electrolyte).
- Expensive slides.
- Price: $5,200 (DT60), $3,075 (DTE).

SUMMARY OF DEMONSTRATION OF NOVA BIOMEDICAL EQUIPMENT

Date: 30 November 1989, 8:30 a.m.

Demonstration by: Wayne Brent, Senior Sales Representative
(713) 578-7045, (800) 458-5813

Equipment: Nova STATPROFILE 5

Diagnostic Tests: 1, 2, 3, 4

Type: Invasive

a. General Information:

- Measures; Na, K, Cl, Ca, pH, PCO_2, PO_2, HCT, and glucose.
- Base unit and two gas cylinders.
- Cylinders 5" Dia., 20" H.
- A cart can be purchased with the unit.
- The cart is equipped with UPS.
- Calculated parameters; oxygen content, hemoglobin, total CO_2, HCO_3, HbO_2 Sat., correction of blood gases to patient temperature, osmolality.
- Unit operates at 37°C (internally).
- Unit operates best under 30°C; however, operating range is 15-40°C.
- Calibrating gas cylinders are pressurized to 2000 psi and must be replaced when pressure drops below 400-500 psi.
- Gas cylinders expire in 2 years.
- Gas A Contents: 20 percent O_2, 5 percent CO_2, 75 percent nitrogen.
- Gas B Contents: 10 percent CO_2, 90 percent nitrogen.
- Arterial blood/venous whole blood/plasma or serum/urine.
- Analyzes 38 samples per hour.
- Accepts syringes, capillaries, and vacuum tubes.
- Sample size: 250 µl (serum, plasma, whole blood), 100 µl (urine).
- One reagent pack contains everything.
- Start-up calibration time: 7 minutes.
- Automatic two point calibration, every 2 hours from sealed internal standards.
- Single point calibration with samples.
- Manual calibration.
- Preheater to heat up the sample to 37°C.
- Waste container is in the reagents pack.
- Microprocessor-controlled electronics.
- Uses different setups for high altitudes (i.e., Denver uses different tubing). Tubing is replaced usually once a year; however, replacement highly depends on usage.
- Easy to replace tubing, one unit plug-in.
- Electrodes are replaced once a month.
- Electrodes replacement requires training.
- One sample suffices for all tests.
- Analysis time for first sample 140 seconds, after that 95 seconds.
- Very fast unit.
- Easy to operate.
- Requires refrigeration for glucose caps.
- Equipped with ticket printer.
- Printer hookup (two ports).
- Internal humidifier (all blood gas analyzers have humidifiers to simulate human body).

- Possible to use smaller gas bottles.
- Modem connection.
- Uses Ion Selective Electrode for Na, K, Cl, Ca, pH, Severinghaus electrode for PCO_2, Clark electrode for PO_2, impedance electrode for hematocrit, and enzyme electrode for glucose.

b. Power: 110/120, 200/220/240V, 50/60 Hz.

c. Calibration:

1. Automatic 2-point calibration every 2 hours.
2. Manually initiated calibrations.
3. Single point calibration.
4. High altitude set ups for tubing.

d. Vibration Tests: None.

e. Interference Tests: None.

f. Dimensions: 23-inches deep x 22.5 inches wide x 18.75 inches high.

g. Weight: 100 pounds.

h. Display: Medium size 44 column, green phosphor.

i. Other Products:

- Several STAT profile analyzers [e.g., STAT PROFILE (1-6)].
- Several bench type analyzers [e.g., Nova (1-12)].

j. Comments:

- Complete diagnostic tests.
- Portable, despite weight and size, by using a cart equipped with UPS.
- Easy to operate and very fast results.
- BUN will be added in near future.
- Calibration manually in 7.5 minutes.
- Simultaneous measurement from one sample.
- Uses whole blood and will do blood gases.
- Easy to replace tubing.
- Requires refrigeration for glucose caps.

SUMMARY OF DEMONSTRATION BY SERADYN DIAGNOSTICS

Date: 17 November 1989, 1:00 p.m.

Demonstration by: Debra Anderson, MT (ASCP)
Diagnostic Sales Specialist
(800) 428-4007, (800) 468-9230

Attendees: J. Eftekhar, P. Olivier

Equipment: Quick - Lyte

Diagnostic Tests: 2

Type: Invasive

a. General Information:

- Uses plasma, serum, or urine.
- Sample size 200 µl, vial is required.
- ISE technology (electrodes; Na, K, and reference).
- Long electrodes' life, must be replaced annually.
- Uses a pipet.
- Very small display.
- Very easy to use.
- Instructions are displayed.
- Records voltage changes of sodium and potassium ions during calibration.
- Displays results in less than 2 minutes; 45 seconds for reference, 63 seconds for sample.
- Printer connection.
- Reagents may be kept at room temperature.
- Electrical grounding to prevent some interference.

b. Power: N/A

c. Calibration: N/A

d. Vibration Tests: None.

e. Interference Tests: None.

f. Dimensions: Small.

g. Weight: Relatively light.

h. Display: LED, small.

i. Other Products: Quick Count, counts hemoglobin and white blood cells.

j. Comments:

- Requires a centrifuge for serum.
- Only tests Na, and K (electrolytes).
- Easy operation.
- Price $2500.

SUMMARY OF TELECONFERENCE WITH BECKMAN INSTRUMENTS

Date: October 1989

Telephone Conference with: Rick Ericksen
9307 Brook Circle
San Antonio, Texas 78240
(512) 696-4922, (714) 993-5321

a. General Information:

1. Glucose Analyzer 2.
   - Serum, plasma or urine.
   - 67 samples/hour.
   - Sample size: 10 µl.
   - Size: 15H X 14W X 12D in.
   - Weight: 40 pounds.
   - Reagent kit: glucose oxidase, aqueous standard.
   - Disposable pipet tips.
   - LED display.
   - Price: $5,200.

2. Microfuge II
   - Small size.
   - Tube size up to 1.5 or 1.8 ml.
   - Speed control up to 13,500 rpm.
   - Equipped with door interlock.
   - Capacity: 48 x 250 µl tubes.
   - Size: 12H x 9.5W x 14.25D in.
   - Weight: 27 lbs.
   - Price: $2,365 (+ $635 for rotors)

3. LABLYTE 800
   - Measures Na, K (electrolytes).
   - Uses whole blood, serum, plasma, or urine.
   - Ion Selective Electrode Technology.
   - 45 samples per hour manual, 70 samples per hour automated.
   - Auto calibration; one and two point.
   - Programmable correlation factors.
   - Easy to operate.
   - RS-232 computer interface.
   - Reference electrode; calomel.
   - Na electrode; Na sensitive glass capillary.
   - K electrode; K sensitive liquid membrane.
   - Sample volume: 120 µl.
   - Power: 100 to 240 VAC, 50/60 Hz, 50 W.
   - Size: 13.4H x 11.8W x 10.6D in.
   - Weight: 24 pounds.
   - Price: Approx. $7,500.

SUMMARY OF TELECONFERENCE WITH BIOCHEM LABORATORY SYSTEMS

Date: December 1989

Company: Bio-Chem Laboratory Systems, Inc.
1650 Oak St.
Lakewood, New Jersey 08701
(800) 345-ATAC

a. General Information:

1. ATAC ISE Electrolyte Analyzer.
   - Measures Na, K.
   - ISE technology.
   - Specimens: whole blood, serum, plasma, and urine.
   - Test results in 80 seconds.
   - Disposable pack.
   - Prepackaged reagents.
   - Waste reservoir.
   - Auto calibration.
   - RS-232 computer interface.
   - Sample size: 100 µl (blood).
   - Power: 110 VAC, 60 Hz.
   - Size: 16.5H x 9.5W x 8.0W in.
   - Weight: 13 lbs.
   - Price: $5,595.

SUMMARY OF TELECONFERENCE WITH CIBA CORNING

Date: October 1989

Personal Contact: William E. Belloli
(800) 225-3232

Equipment: 288 Blood Gas System

Diagnostic Tests: 1, 2

a. General Information:

- Blood gas, electrolytes, and hemoglobin.
- Measured Parameters; pH, PO_2, PCO_2, Na, K, Cl, Ca, total hemoglobin, barometric pressure.
- Runs up to 35 samples per hour.
- Ticket printer.
- Display.
- Three RS-232 computer ports.
- Can interface co-oximeter.
- Self diagnostic for maintenance.
- Sample Size: 200 µl of whole blood.
- Method of presentation: syringe or capillary.
- Dimensions: 16H x 25.5W x 19D inch.
- Weight: 74 lbs.
- Power: 100/120/220/240 VAC, 50/60 Hz, ± 10 percent.

SUMMARY OF TELECONFERENCE ON MALLINCKRODT EQUIPMENT

Date: 15 January 1990 and 1 May 1990

Telephone Conference with: Brian Wargetz
(800) 262-3654

Equipment: GEM-STAT

Diagnostic Tests: 1, 2, 3

Type: Invasive

a. General Information:

- Uses one disposable cartridge (STATPAK cartridge).
- Cartridge consists of solutions, waste bag, and electrodes.
- Delivers results on 11 parameters; pH, PO_2, PCO_2, K, Ca, Na, HCT, Base Excess, HCO_3, TCO_2, HbO_2 Sat.
- Uses one sample, (500 µl) for all tests.
- No special skills required to operate equipment.
- No calibration by operator (two-point every 60 minutes and one-point after each sample).
- No special training required.
- Start-up calibration 52 minutes (45 minutes for cartridge warm-up and 7 minutes for QC).
- No maintenance by operator, no cleaning, sensors must be changed every 72 hours, tubing every 24 hours.
- Start up calibration.
- Auto calibration every hour for 5 minutes (no testing allowed during calibration).
- Auto temperature correction.
- Patient-side convenience.
- No special storage requirements for cartridges.
- Cartridge lasts for 50 samples.
- Cartridge costs approximately $325.
- Unit price approximately $21,000.
- Cost per test $6.50.
- Quality control solution costs approximately $100/carton (30 units).
- Uses three quality control solutions for new cartridges.
- Very similar to Nova STATPROFILE units but miniaturized analyzers.
- McDonnell Douglas is evaluating the unit to be used on space shuttle.
- No gas cylinders.
- Power loss: Less than 30 minutes (uses battery back-up), requires auto recalibration (5 minutes). Over 30 minutes requires start-up calibration (52 minutes).
- Glucose will be added in about 3 years.
- Some other tests will also be added.
- Correlation factor for Ca, 0.92; HCT, 0.85.
- Screen is visible in poor lighting conditions.
- No vibration test.
- No interference test.
- Pressure calibration must be done by the software.
- Takes 1 minute, 48 seconds to obtain data.
- Requires preheparinized syringes.
- Only 20 minutes' training instructions.
- Shelf life for cartridges: 4 months.

b. Other Information Obtained from Catalog:

- Equipped with ticket printer.
- Small size 8.4H X 18.3D X 9.1W inches.
- Internal temperature control and correction.
- Testing and analysis time 109 seconds.
- Automatic calibration.
- Wet chemistry using STATPAK cartridge.
- Cartridge locks in the unit.
- Heparinized whole blood sample.
- Status updates on remaining sample capacity.
- Thirty minutes' battery backup.
- Quality control GEM-CHECK are all cartridges is mandatory.
- RS-232 computer port.
- Cartridge storage at room temperature.
- Uses miniaturized version of electrochemical sensors.
  Oxygen: "Clark style" polarographic.
  Carbon dioxide: "Severinghaus" CO_2 electrode.
  pH, electrolytes: ISE.
  HCT: Electrical conductivity.

c. Power: 120 VAC + 10 percent - 15 percent, 60 Hz, 100 W.

d. Calibration: Two-point every hour, one-point between samples.

e. Vibration Tests: None.

f. Interference Tests: None.

g. Dimensions: 8.4 inch x 18.3 inch x 9.1 inch.

h. Weight: 27 pounds.

i. Display: LED.

j. Comments:

- No glucose (will be added in near future).
- Small size.
- Lightweight.
- Patient-side convenience.
- Uses whole blood.
- Very easy to operate.
- Auto calibration.
- Low maintenance due to use of cartridge.
- Refrigeration is not required for cartridges.
- Sample presentation to the unit under vibrating environment is questionable.
- 109 seconds test time.
- Price per test: $6.50/sample.

SUMMARY OF TELECONFERENCE WITH MEDICA

Date: October 1989

Company: Medica
14 De Angelo Drive
Bedford, MA 01730
(800) 777-Lyte

Equipment: Easylyte

a. General Information:

- Measures Na, K (electrolytes).
- Sample: whole blood, serum, plasma, or urine.
- Sample size: 100 µl.
- Analysis time: 80 seconds for blood.
- Small size, portable.
- Auto/manual calibration.
- RS-232 computer interface.
- Size: 16.5 inches H x 9.5 inches W x 8.0 inches D.
- Weight: 13 pounds.
- External thermal printer.
- LCD display.
- Easy to operate.
- Uses sample tube and probe for presenting samples to analyzer.
- Syringe sample can also be used.
- Requires daily cleaning.
- Uses solution packs.
- Easy to install new solution packs.
- Power: 110 VAC or 220 VAC, 60/50 Hz.

SUMMARY OF TELECONFERENCE WITH MILES DIAGNOSTICS

Date: 17 November 1989 and 20 November 1989

Telephone Conference with: Robert Mattis, Hospital Representative
Miles Inc.
11203 Lago Vista
Helotes, Texas 78023
(512) 695-9353

Equipment: Clinistat

Diagnostic Tests: 2 (K only), 4

a. General Information:

- Dry chemistry analyzer.
- Uses slides.
- Ticket printer.
- Tests: Glucose, BUN, K, hemoglobin, cholesterol, triglycerides, AST, ALT, uric acid, albumin, AP, LDH.
- Slides are foil wrapped (humidity proof).
- Internal disposal basket.
- Calibration by operator using keyboard.
- Accepts up to 19 tests at a time.
- First test results in 7 minutes, one every 8-10 seconds thereafter.
- 80 tests an hour.
- Touch key control panel.
- Small size.
- Patient-side convenience.
- LED display.

SUMMARY OF TELECONFERENCE WITH NOVA BIOMEDICAL

Date: 24 October 1989

Telephone Conference with: Kate Reed

Equipment: Nova STATPROFILE 5

a. General Information:

- Unit has been tested in a pressure chamber.
- A barometer calibrates and adjusts pressure.
- With large or rapid changes in barometric pressure, test results are inaccurate.
- All measurements are in gauge pressure, adjusted for surrounding pressure.
- No vibration tests.
- Unit has internal transformers with internal voltages of 5 VDC, 15 VDC, $\pm$ 12 VDC, and 27 VDC for printer.
- Lactate measurement will be added in near future.
- BUN can be measured by another unit (not available on STATPROFILE 5).
- Uses needle to collect samples.

SUMMARY OF TELECONFERENCE WITH STATSPIN TECHNOLOGIES

Date: October 1989

Telephone Conference with: Robert Mathis
588 Pleasant Street
Norwood, MA 02062

Equipment: STATSPIN V CENTRIFUGE

a. General Information:

- Bench top unit.
- Analyzes plasma in 30 seconds.
- Method of collection: venipuncture or finger stick.
- Accommodates nearly all capillary blood collectors.
- Spun HCT in 120 seconds, sample size 10 µl.
- Self balancing head, reduces vibration.
- Low noise.
- Recommended for ambulatory care facilities.

b. Size: 6 x 6 x 9 in.

c. Weight: 5 pounds.

d. Other Equipment: STATSPIN IV, III, II and I.

Appendix B

AMCL EQUIPMENT DATABASE

INTRODUCTION

The database containing information about the "invasive" clinical laboratory equipment is described in this appendix. This software is designed to run on IBM compatible personal computers with 640K RAM, a hard disk and a 5 1/4-inch floppy drive.

CLIPS resides on two double-sided, double-density 5 1/4-inch diskettes.

LOADING AND USING THE DATABASE

The following section describes how to load CLIPS on the hard disk and then use the database: (1) create a directory to hold CLIPS, (2) load the CLIPS files from the two floppy diskettes, (3) type CLIPSWIN to enter the program.

You are now in the CLIPS environment and the computer screen should appear as shown in Figure B-1. Across the top of the screen are the basic menu selections: File, Execute, Debug, Action, Examine, Help and Options (Figure B-1). To select an item from this menu, use the arrow keys to highlight the desired selection and press the down arrow key to produce the submenu. Selection of a menu item will result in the display of the associated submenu.

To load the database, highlight the File menu item and press the ENTER key (Figure B-2). From the submenu, select the Load Rules/Deffacts item and press the ENTER key (Figure B-3). Another submenu of files that can be loaded will be displayed. Use the down arrow key to scroll through this submenu until you can highlight the AMCL1.FCT file (Figure B-4). Press the ENTER key to select this file.

The screen will now monitor the compiling of rules and facts in the file AMCL1.FCT. When the screen completely fills, the word MORE will appear in the center of the bottom border. Press the ENTER key to continue the compilation. The screen will completely fill once more, this sequence will be repeated until all of the data in the AMCL1.FCT file has been added to the program and the CLIPS> prompt is at the bottom (Figures B-5, B-6, B-7).

Highlight the Execute item in the main menu to execute the rules in the database and press the ENTER key. Highlight Reset from among the submenu items and press the ENTER key. Now select Run from the submenu and press the ENTER key (Figures B-8, B-9, B-10).

A portion of the main menu of the AMCL SELECTOR is now displayed; press ENTER key to display the rest of this menu (Figure B-11). Type the appropriate number for the diagnostic test on which you wish to sort the database. Selecting Item 2 for ELECTROLYTES produces a display as shown in Figure B-12. Press the ENTER key to sort through the database for the equipment which performs the selected test. Type a second number and press ENTER key if you wish to further sort among the initial candidates (Figure B-13). Selecting 3 for BLOOD GASES produces Figure B-14. Repeat the above steps to further limit the choices of candidates.

Once all of the desired diagnostic tests have been selected, type k and press the ENTER key to produce a list of the diagnostic tests for which the database has been sorted (Figure B-15). Type p and press the ENTER key to produce a list of the candidates that will perform all of the selected diagnostic tests (Figure B-16). For permanent record, use the PRINT SCREEN command.

To perform an independent sort of diagnostic tests, type q and press ENTER key which returns the computer to the DOS prompt.

ADDING EQUIPMENT INFORMATION TO THE DATABASE

Additional equipment can be added to the database within the fields which have already been established. See the CLIPS manual for instructions on how to proceed. The manual also contains a tutorial.

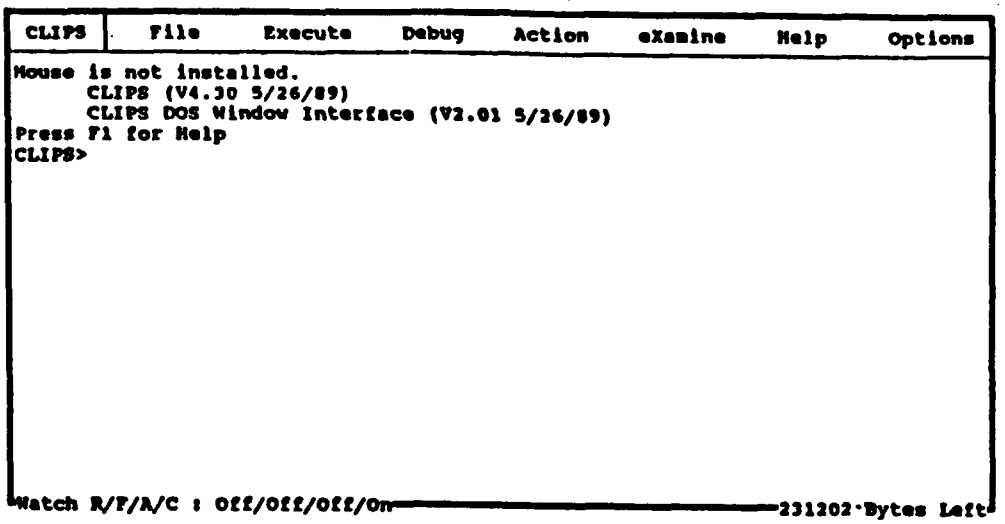

Figure B-1.

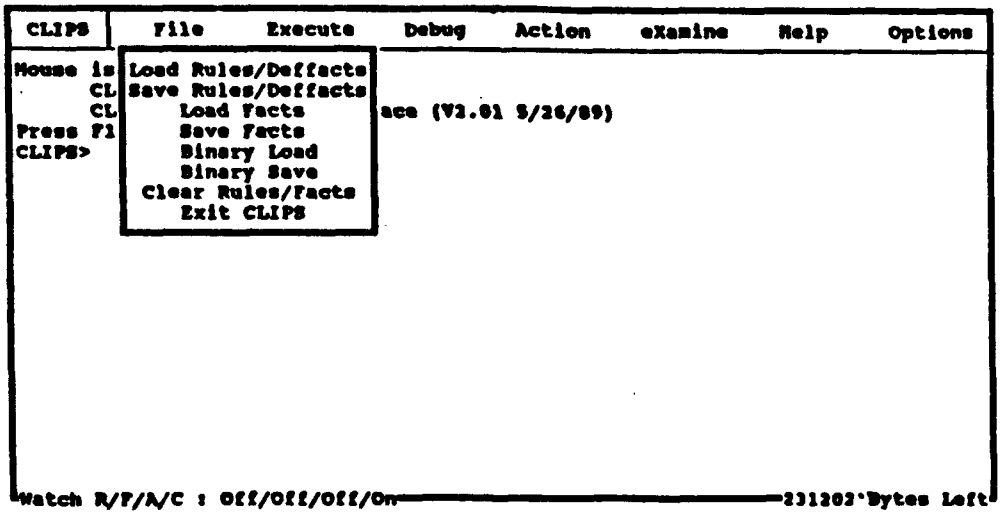

Figure B-2.

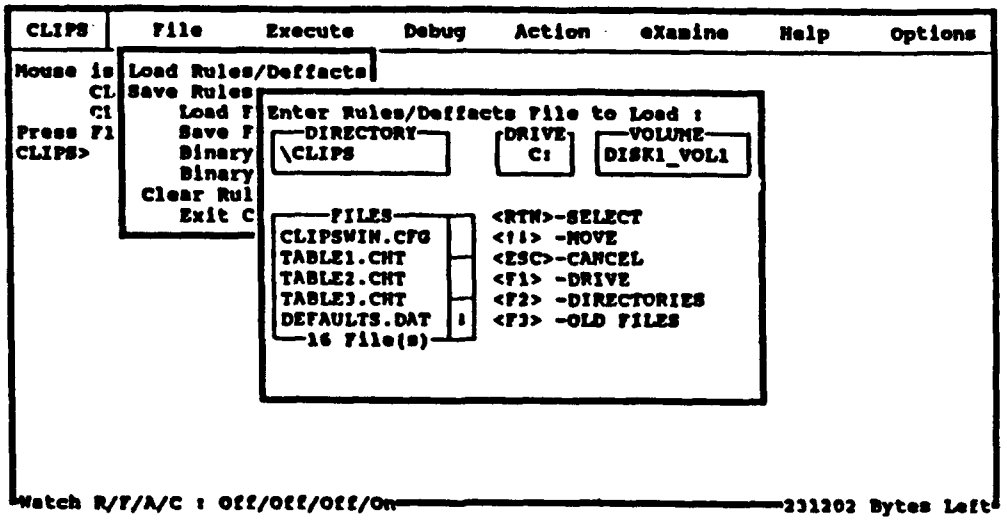

Figure B-3.

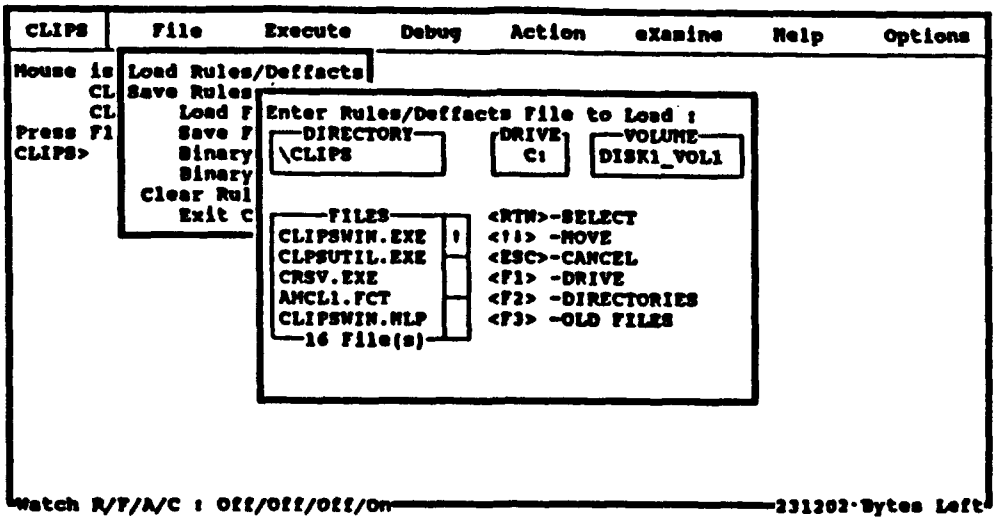

Figure B-4.

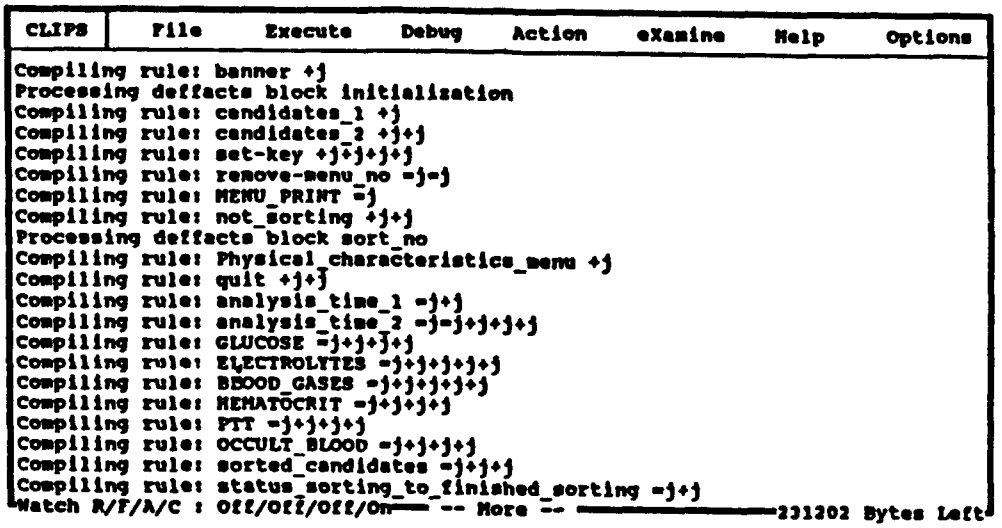

Figure B-5.

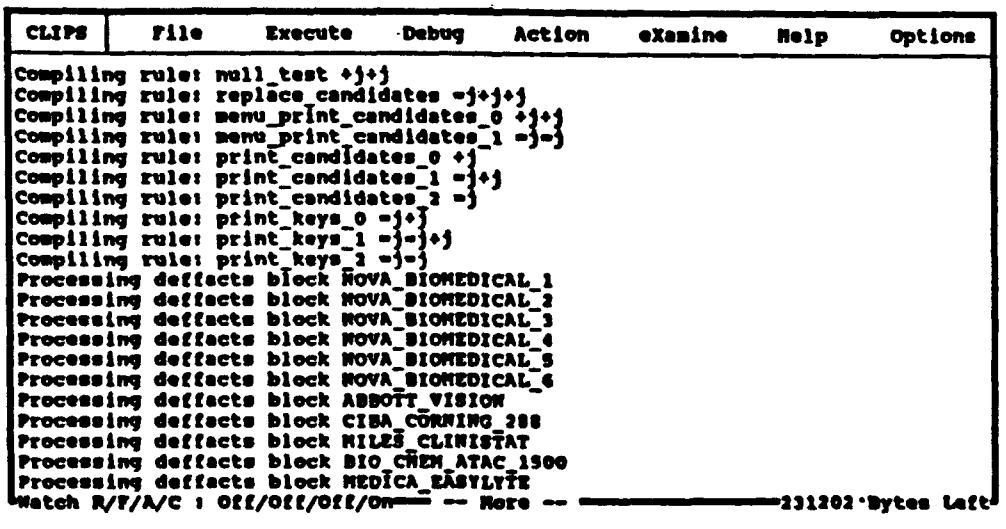

Figure B-6.

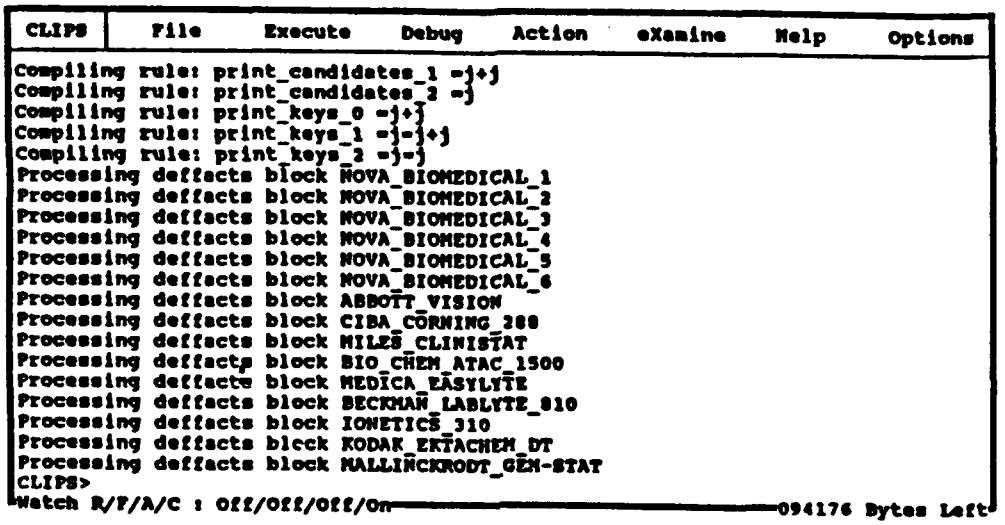

Figure B-7.

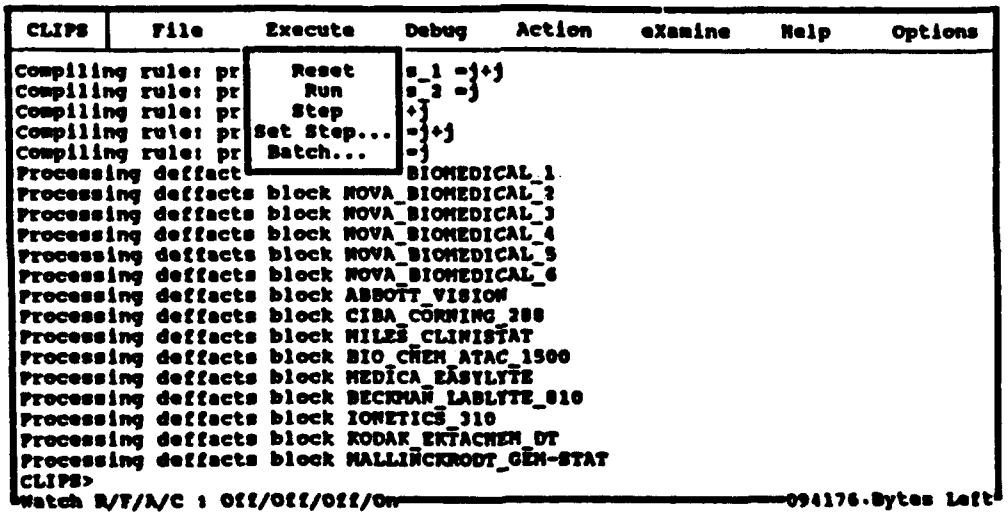

Figure B-8.

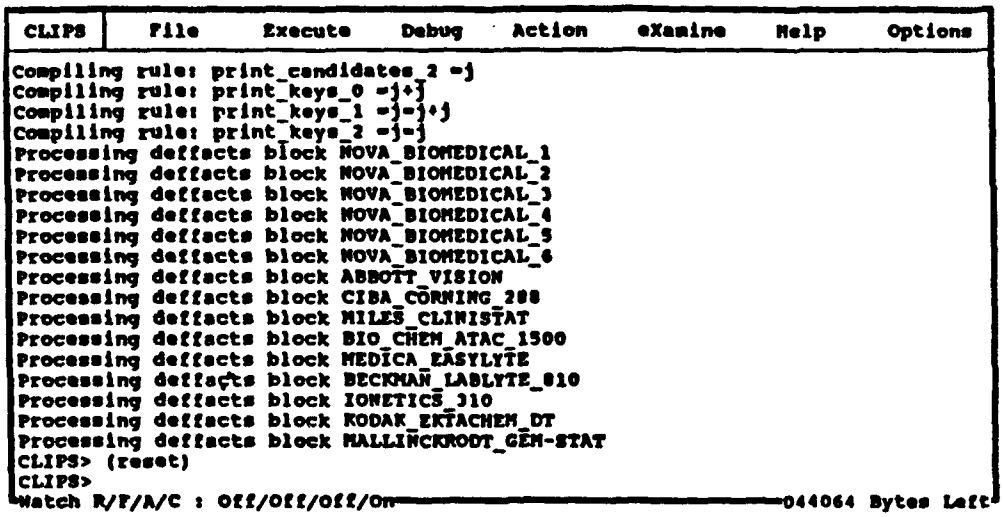

Figure B-9.

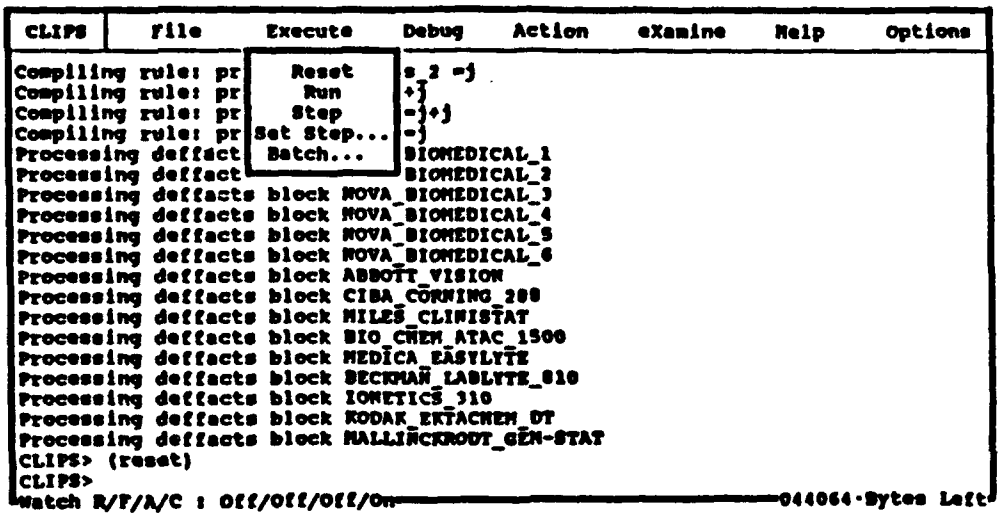

Figure B-10.

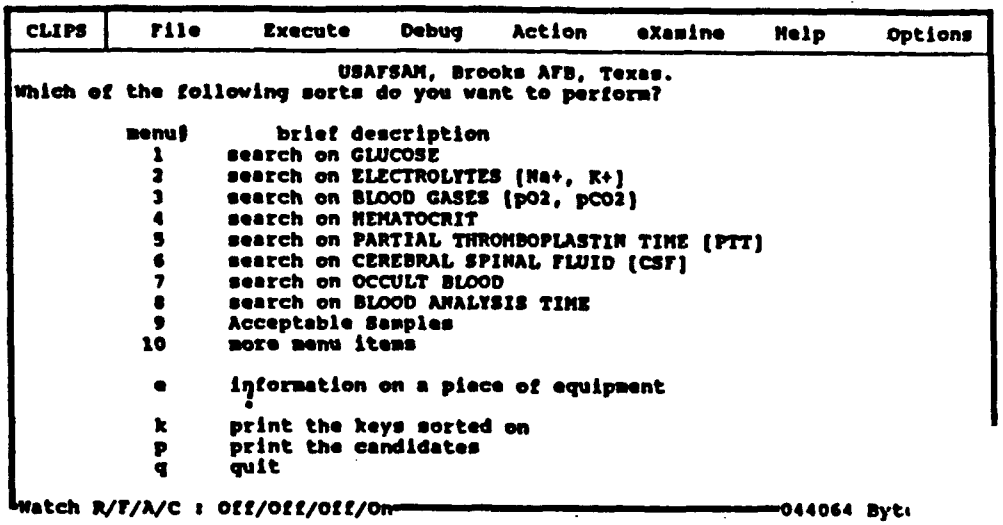

Figure B-11.

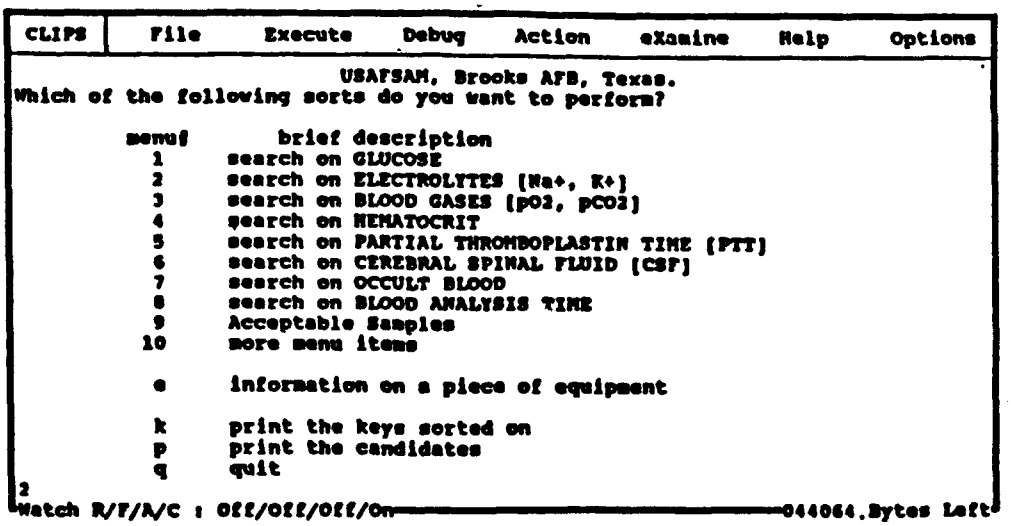

Figure B-12.

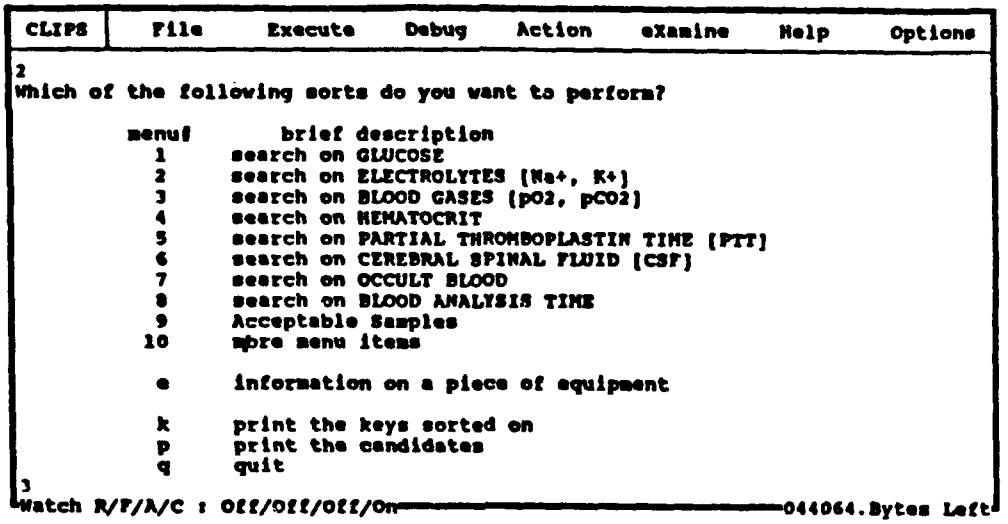

Figure B-13.

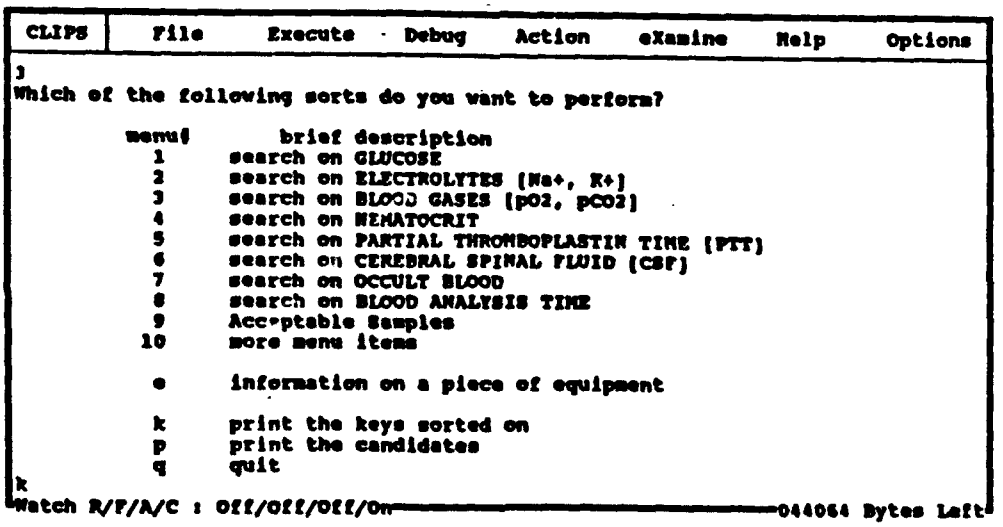

Figure B-14.

```
CLIPS | File  Execute  Debug  Action  eXamine  Help  Options

The keys that you sorted on were
        BLOOD_GASES              ELECTROLYTES
Which of the following sorts do you want to perform?

        menu#       brief description
          1     search on GLUCOSE
          2     search on ELECTROLYTES (Na+, K+)
          3     search on BLOOD GASES (pO2, pCO2)
          4     search on HEMATOCRIT
          5     search on PARTIAL THROMBOPLASTIN TIME (PTT)
          6     search on CEREBRAL SPINAL FLUID (CSF)
          7     search on OCCULT BLOOD
          8     search on BLOOD ANALYSIS TIME
          9     Acceptable Samples
         10     more menu items

          e     information on a piece of equipment

          k     print the keys sorted on
          p     print the candidates
          q     quit
Watch R/F/A/C : Off/Off/Off/On---- -- More -- ----------044064 Bytes Left
```

Figure B-15.

```
CLIPS | File  Execute  Debug  Action  eXamine  Help  Options

          1     search on GLUCOSE
          2     search on ELECTROLYTES (Na+, K+)
          3     search on BLOOD GASES (pO2, pCO2)
          4     search on HEMATOCRIT
          5     search on PARTIAL THROMBOPLASTIN TIME (PTT)
          6     search on CEREBRAL SPINAL FLUID (CSF)
          7     search on OCCULT BLOOD
          8     search on BLOOD ANALYSIS TIME
          9     Acceptable Samples
         10     more menu items

          e     information on a piece of equipment

          k     print the keys sorted on
          p     print the candidates
          q     quit
p
The candidates are:
        NOVA_BIOMEDICAL_2       NOVA_BIOMEDICAL_4       NOVA_BIOMEDICAL_5
        HALLINCKRODT_GEM-STAT       NOVA_BIOMEDICAL_1
type RETURN when ready to return to the main menu
Watch R/F/A/C : Off/Off/Off/On----------044064 Bytes Left
```

Figure B-16.

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